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# STUDIES WITH THE BACTERIOPHAGE OF RHIZOBIA[1]

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The influence of a wide variety of physical and chemical agents on bacteriophage has been the subject of numerous highly productive investigations. Comparatively little is known, however, of the effect of these agents on the susceptibility or resistance of the host cells to a homologous lytic principle. This is an important consideration in various practical aspects of bacteriophagy. For example, if conditions in the animal or plant body favour dissociation of a susceptible organism to one comprising predominantly resistant cells (which may be even more virulent than the original susceptible culture) the therapeutic action of a homologous phage will be almost completely obviated (4). With organisms such as rhizobia, beneficial to man, a change from susceptibility to resistance would be highly desirable as it would militate against the destructive action of *Rhizobium* phage (2) and thus overcome a threat to symbiosis between these organisms and their host. Similarly, factors favouring an increased resistance of lactic acid streptococci will decrease the possibility of interference by phage in starter cultures or cheese vats (10).

It is generally conceded that actively multiplying cells lyse most readily. This state of cellular activity presupposes, therefore, a medium and a temperature favourable to the organisms. However, if the composition of the medium is such as to favour gum production, it will render the cells more resistant to a given phage because of the mechanical shielding action of the gum (4, 7).

Maintenance of the organisms in an active state would appear to be a prime consideration in studies involving phage. The work of d'Herelle (3) and Laird (8) support this view. The former investigator found that a suspension of a 24-hour culture of dysentery organisms lysed completely, whereas a 15-day old culture underwent only partial dissolution. This may have been due not to a change in the sensitivity of the cells themselves but perhaps to the death of susceptible ones and to the relative increase of resistant cells present in the same culture. Laird (8) states that certain strains of rhizobia change radically in their response to phage if not maintained in an active condition. This investigator seeded 12 strains of *Rhizobium trifolii*, 7 of which were resistant to phage, on mannitol yeast-water agar slants under identical conditions and stored them at room temperature (18 to 20° C.) making no attempt to prevent evaporation of moisture from the agar. After 6 months when only a crisp mass of the

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original agar remained he found that the susceptible strains had died out. In a similar set of experiments he determined the susceptibility to lysis of the same organisms when some moisture was still present in the agar slants. The 12 strains grew, but the sensitive ones showed only very slight susceptibility to the lytic agent. Again on testing 8-week old cultures for lysis and comparing the results with lysis of corresponding strains which had been transferred every second day he found that "there was evidence of a greater degree of resistance" with old than with young cultures.

Under the dynamic conditions existing in soils, bacteria are subjected to a constantly changing environment (wetting and drying, freezing and thawing) which may well influence their susceptibility or resistance to phage. The following experiments were designed to study by means of Laird's technique (6, 8) the effects of temperature, desiccation, and aging on the susceptibility or resistance of strains of rhizobia to lysis.

## EXPERIMENTAL

Studies of a preliminary nature were made with one strain of vetch and one of pea organisms and their homologous phages. The bacteria were inoculated on mannitol yeast-water agar slants and incubated at 28° C. for 48 hours. Cultures of each strain were then divided into 2 equal parts; one was maintained at 20° C. and the other at 0° C., no attempt being made to prevent evaporation of moisture from the agar. At weekly intervals 3 cultures of each strain at 0° C. and at 20° C. were each inoculated into 6 tubes containing 10 cc. of a yeast-water medium. After 24 hours' incubation, 5 of the 6 turbid fluid cultures received 0.3 cc. of active homologous phage, then all cultures were reincubated and examined for lysis every 24 hours; the sixth tube receiving no phage served as a control. A similar procedure was employed with the 2 mother strains which were maintained in an active condition by weekly transfers. The lytic agents employed in all tests were 5 days old and were always tested against the homologous strains before being used. Concurrently note was taken of the growth in fluid media, cultural characteristics of the organisms maintained at the 2 temperatures, and the degree of desiccation of the agar.

The cultural characteristics of the organisms suffered little change beyond a slight increase in viscosity after 4 weeks. There was no appreciable loss of moisture from the agar slants maintained at 0° C., whereas those at room temperature lost almost one-half to two-thirds of their original volume within the time of the experiment.

Table 1 is illustrative of the results obtained. Only 1 of the 6 tubes inoculated with each culture tested is indicated, but the results are quite representative. There was little significant change in the susceptibility of the organisms except possibly of the vetch cultures at 0° C. after 10 weeks.

Further experiments were planned with a very active *Rh. meliloti* phage isolated from soil and with 6 resistant and 6 susceptible homologous cultures. Each culture was treated as follows. It was transferred to mannitol yeast-water agar slants which were incubated for 48 hours at

TABLE 1.—LYSIS OF CULTURES OF VETCH AND PEA NODULE BACTERIA INCUBATED AT 0° C. AND 20° C. FOR DIFFERENT PERIODS OF TIME

| Organism | Vetch | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weeks of incubation | 1 | | | | | | 10 | | | | | | Cult. trans. weekly | |
| Temp. of incubation | 0° C. | | | 20° C. | | | 0° C. | | | 20° C. | | | 0° C. | 20° C. |
| Replicate cultures tested | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 1 |
| Contact with phage (hrs.) | | | | | | | | | | | | | | |
| 24 | 4* | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 48 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 72 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 3 |
| 92 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 |

| Organism | Pea | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weeks of incubation | 4 | | | | | | 14 | | | | | | Cult. trans. weekly | |
| Temp. of incubation | 0° C. | | | 20° C. | | | 0° C. | | | 20° C. | | | 0° C. | 20° C. |
| Replicate cultures tested | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 1 |
| Contact with phage (hrs.) | | | | | | | | | | | | | | |
| 24 | 3 | 4 | 3 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 48 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| 72 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 92 | – | 1 | 1 | – | – | – | 1 | – | 2 | 1 | 1 | 1 | 2 | 2 |

*4 = complete clearing; 3 = almost complete; 2 = definitely clearer than control; 1 = slight clearing; – = turbid as control.

28° C. The resulting cultures were divided into 2 equal lots, one to be kept at 28° C., the other at 0° C. Each lot was again halved; one half was sealed with paraffin, the other left unsealed to permit evaporation of moisture. Two slants of sealed and unsealed cultures from those kept at both temperatures were removed periodically for testing. A suspension of each culture was made with a yeast-water medium and 3 fluid cultures prepared by addition of the suspension to fresh media until a turbidity was obtained which corresponded to approximately 250,000,000 bacteria per cc. (equivalent to the turbidity of a 24-hour culture). Two of the fluid cultures thus obtained received 1 cc. of active phage each, the third tube served as control. These 3 tubes are designated as the Z series. At the same time, 3 tubes of fluid media received 1 drop each of the bacterial suspension and were incubated. When turbidity had developed (after 24 hours at the beginning of the experiment and after 30 to 60 hours during the later stages) phage was added to 2 of the cultures; the third was left as control. These 3 cultures are designated as the H series. By this means viability of the organisms was tested and also lysis of growing cells as compared with lysis of a suspension of cells (although some growth occurs in the latter also). Observations for lysis were made daily. Actively maintained mother cultures (transferred weekly) were tested in a similar manner. The lytic principle was always freshly prepared and tested prior to every test period.

After unsealed cultures had dried out completely (cultures at 28° C. after 3 and those at 0° C. after 15 months) 5 cc. of fluid medium were added to each type and the culture incubated until turbidity developed. This culture was then used "in lieu" of the suspension prepared as described above.

A slight increase in viscosity was observed in all the cultures after 3 months incubation. After 5 months all susceptible strains developed a dull brownish tinge which became accentuated with time and was in distinct contrast to the white-grey, glistening growth of the resistant and actively maintained strains. During the first 6 months the turbidity of the cultures of the H series was equal to that of a fresh 24-hour culture. After 6 months such turbidity was developed only within 32 to 48 hours and after 16 months within 48 to 60 hours. Phage was added immediately after maximum turbidity had developed.

The data presented in Table 2 are representative of the results obtained. Only one of the fluid cultures of the duplicate test slants of one strain is presented since the results of duplicate tests were almost identical. It is quite apparent that the factors of temperature, aging, and desiccation of the medium have not materially affected the susceptibility of *Rh. meliloti* strains to lysis. None of the resistant cultures tested manifested any tendency to susceptibility to phage. Whenever susceptible test cultures were transferred to fresh agar and treated with phage, complete dissolution was obtained. Plating of all test and active cultures after 12 and 24 months treatment and picking of 200 colonies of each culture yielded no resistant organisms from susceptible strains or susceptible forms from resistant strains.

TABLE 2.—INFLUENCE OF TEMPERATURE, AGING AND DESICCATION ON LYSIS OF A STRAIN OF *Rh. meliloti*

| Temp. of incubation | 0° C. | | | | | | | | | | | | 28° C. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Sealed | | | | | | Unsealed | | | | | | Sealed | | | | | | Unsealed | | | | | |
| Series* | Z | | | H | | | Z | | | H | | | Z | | | H | | | Z | | | H | | |
| Cultures tested† | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| Period of sampling (mos.) | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Exposure to phage (hrs.) | ‡ | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| 48 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 72 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 96 | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Period of sampling (mos.) | 6 | | | | | | | | | | | | | | | | | | | | | | | |
| Exposure to phage (hrs.) | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 |
| 48 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 |
| 72 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 3 |
| 96 | 2 | 3 | 3 | 4 | 3 | 3 | 2 | 2 | 4 | 4 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Period of sampling (mos.) | 12 | | | | | | | | | | | | | | | | | | | | | | | |
| Exposure to phage (hrs.) | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 48 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 |
| 72 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 2 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 2 | 3 |
| 96 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| Period of sampling (mos.) | 24 | | | | | | | | | | | | | | | | | | | | | | | |
| Exposure to phage (hrs.) | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 48 | 4 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 72 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 4 |
| 96 | 3 | 2 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |

*Z phage added along with inoculum. H phage added to turbid culture.

†a, b—duplicate test agar cultures, c—actively maintained agar culture.

‡—Numbers refer to degree of lysis (Table 1).

In order to determine whether constant transfer of phage increased its potency so as to render it sufficiently "virulent" to attack organisms which had undergone some slight changes in susceptibility, and thereby make conclusions from observations of lysis subject to misinterpretation, the concentration of the lytic principle was tested periodically by the dilution method, but little change was noted (Table 3).

Table 3.—Influence of frequent transfer of phage on its potency for *Rh. Meliloti*

| Test period (months) | Phage dilution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $10^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ | $10^{-11}$ |
| 0 | 4* | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |
| 6 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 |
| 12 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 |
| 18 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |
| 24 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |

*Numbers refer to degree of lysis (Table 1).

At the same time, another experiment was carried out on the effect of aging on the "virulence" of phage. To this end, phage was transferred to a number of tubes which were then sealed with paraffin and divided into 2 lots, one of which was placed at 0° C., the other at 28° C. The change in potency was again determined by the dilution method (Table 4). It is commonly acknowledged that viruses resist lower temperatures more readily than higher ones, and phage is no exception (1, 9).

Table 4.—Influence of time and Temperature on the longevity of *Rhizobium* phage

| Period of sampling (months) | Temperature of incubation | |
|---|---|---|
| | 0° C. | 28° C. |
| 0 | $10^{-9}$* | $10^{-9}$ |
| 6 | $10^{-9}$ | $10^{-9}$ |
| 12 | $10^{-9}$ | $10^{-7}$ |
| 18 | $10^{-9}$ | $10^{-6}$ |
| 24 | $10^{-9}$ | — |
| 30 | $10^{-8}$ | — |
| 40 | $10^{-5}$ | — |

*Figures indicate highest dilution at which complete clearing occurred.

Phage is also known to decrease in potency more rapidly at high than at low dilutions (1). This was borne out by the following experiment. Three dilutions of phage, $10^{-5}$, $10^{-6}$, and $10^{-7}$, maintained at 28° C., were analysed periodically for phage content by means of a plaque technique described in a previous paper (5). Results were compared with those obtained concurrently by testing the original undiluted filtrate at high dilutions. The lytic agent obviously decreases in potency more rapidly at high dilutions than in a concentrated form (Table 5).

TABLE 5.—EFFECT OF DILUTION AND TIME ON POTENCY OF *Rhizobium* PHAGE*

| Test period (days) | Phage dilutions tested | | | Original phage at dilutions of | | |
|---|---|---|---|---|---|---|
| | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ |
| 0 | confluent plaques | confluent plaques | 94 | confluent plaques | confluent plaques | 94 |
| 7 | confluent plaques | confluent plaques | 39 | confluent plaques | confluent plaques | 96 |
| 17 | confluent plaques | 124 | 12 | confluent plaques | confluent plaques | 90 |
| 28 | confluent plaques | 53 | 6 | confluent plaques | confluent plaques | 93 |
| 38 | 213 | 18 | 1 | confluent plaques | confluent plaques | 89 |
| 54 | 51 | 0 | 0 | confluent plaques | confluent plaques | 84 |

*Number of plaques per cc. (average of three plates).

## SUMMARY

The factors of age of culture, temperature, and desiccation did not appear to alter the resistance or susceptibility of the strains of rhizobia studied with the possible exception of a vetch strain maintained for 10 weeks at 0° C. which seemed to dissolve less readily than the actively maintained control. Organisms whose viability had evidently decreased (as indicated by failure to produce turbidity within 24 hours) dissolved completely. Nor were the susceptible strains less viable than the resistant ones as Laird (8) observed.

The above results do not necessarily contradict those of Laird since it is well known that genus *Rhizobium* includes many organisms varying considerably both morphologically and physiologically. It is therefore entirely possible that some strains will suffer change as a result of the above treatment and others will not. However, resistant strains, appear to have been unaffected by the conditions imposed on them.

Bacteriophage of rhizobia retains its potency for years at 0° C. but decreases in virulence at 28° C., especially at high dilutions.

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# THE INHERITANCE OF SOLID STEM AND CERTAIN OTHER CHARACTERS IN CROSSES BETWEEN VARIETIES OF *TRITICUM VULGARE*[1]

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Solid-stemmed wheat varieties are more resistant to damage by the western wheat-stem saw-fly *(Cephus cinctus)* than are hollow-stemmed varieties according to the results of Kemp (6) and of Farstad (3). Resistance appeared to be due to the solid-stem character which tended to inhibit the growth and development of the larvae.

The wheat breeding program at this Station is concerned with the production of new agronomically desirable varieties having solid stems and, consequently, resistance to sawfly damage. The inheritance studies herein reported are a part of this general program.

## MATERIALS AND METHODS

In 1934 Mr. H. J. Kemp of this Station obtained a number of vulgare type solid-stemmed wheats from Dr. O. Frankel, Lincoln College, Christchurch, New Zealand. Dr. Frankel had originally obtained these wheats from Portugal. Nothing further is known to the authors as to their origin. That they are 42-chromosome wheats is shown by the fact that they cross readily with other varieties of *Triticum vulgare* producing entirely fertile progeny. A number of selections were made from two of the original introductions, S-615 and S-633. Four of these selections, S-615-9, S-615-11, S-633-3 and S-633-23 were used as solid-stemmed parents in these studies.

The hollow-stemmed parents used were the varieties Thatcher and Renown (strain R.L. 716.6). The former was produced at the University of Minnesota from the cross (Marquis × Iumillo) × (Marquis × Kanred) and the latter at the Dominion Rust Research Laboratory from the cross H-44-24 × Reward.

The material used in this study consisted of the $F_1$, $F_2$ and $F_3$ generations of the crosses Thatcher × S-615-11, Thatcher × S-633-23, Renown × S-615-9 and Renown × S-633-3. The contrasting characteristics of the parental varieties that were studied are presented in Table 1.

Table 1.—Characters of parental varieties studied

| Variety | Character studied | | | |
|---|---|---|---|---|
| | Stem solidness | Stem rust reaction | Awns | Chaff colour |
| S615-11 | Solid | Susceptible | Awned | Brown |
| S615-13 | Solid | Susceptible | Awned | Brown |
| S633-3 | Solid | Susceptible | Tip-awned | White |
| S633-23 | Solid | Susceptible | Tip-awned | White |
| Thatcher | Hollow | Resistant | Tip-awned | White |
| Renown | Hollow | Resistant | Tip-awned | White |

[1] Contribution No. 122 from the Cereal Division, Dominion Experimental Station, Swift Current, Experimental Farms Service, Dominion Department of Agriculture.
[2] Cereal assistant, graduate assistant, and chief assistant (agronomy) respectively.

The $F_1$ and $F_2$ plants were grown in rows 5 feet long and 1 foot apart with the plants spaced about 3 inches apart in the rows. Each $F_3$ line was grown in a similar row, approximately 25 seeds being planted in each. Parental varieties were sown at intervals of approximately 20 rows.

The methods of handling and classifying the material, for any individual character, are presented later with the discussion of that character.

The data were analysed according to the methods described by Goulden (4).

## STEM SOLIDNESS

*Literature Review*

Studies on the inheritance of the solid-stem character in wheat crosses have been confined to interspecific crosses in so far as the authors have been able to determine.

Biffen (1) crossed varieties of *Triticum turgidum* with those of *T. vulgare.* He found the $F_1$ to be hollow and the $F_2$ segregated into 3, hollow to 1, solid. He suggests that solidness of stem is not morphologically a simple character.

Engledow (2) using a similar material obtained similar results. He noted, however, that many intermediate types were found. When the material was carried through to the $F_4$ inconsistent results were obtained in breeding behaviour. It is possible that Engledow's material was being affected by environmental factors in the manner described by Platt (9).

Kajanus (5) also used crosses between *T. turgidum* and *T. vulgare.* He found the $F_1$ to be hollow while the $F_2$ was divided into two groups. One group contained no pith, or only a little, while the other showed complete pithiness or nearly so. The relationship of these two groups approached a 3 to 1 ratio. He is inclined, however, to assume 2 factors with the heterozygote intermediate.

Stoll (cited by Kajanus) crossed *T. vulgare* and *T. polonicum.* The $F_1$ was hollow and the $F_2$ segregated into a ratio approaching a 3 to 1.

Von Tschermak (cited by Kanajus) crossed the hollow-stemmed species *T. obtusatum* Kaj. ($n = 42$) with the solid stemmed *T. accuminatum* Kaj. ($n = 28$). The pithy stem seemed to prevail over the hollow stem in the $F_1$. The behaviour of the $F_2$ indicated that a number of genes were responsible for pithiness with a cumulative effect.

Kihara (7) in a cross between *T. vulgare* and *T. durum* found the $F_1$ to be intermediate. Segregation occurred in the $F_2$ while in the $F_3$, selections from extreme plus and minus groups bred true and the intermediate types continued to segregate.

The senior author (unpublished data) crossed several varieties of *T. vulgare* with Golden Ball, a variety of *T. durum.* The $F_1$ was intermediate but approaching the hollow vulgare condition more closely than the solid durum condition.

Yamashita (10) used an extensive series of crosses involving several species to study the genetics of the solid stem character. As a result of his studies he postulates the following factors:

$M_A$, a factor for hollow straw in the *A* genom (no allelomorph of this factor known); $M_d$, a factor for solid straw in the *B* genom of *T. diccoccum* and *T. durum*; $M_p$, a factor for solid straw in *T. polonicum*; $M_t$,

a factor for solid straw in *T. turgidum*; $M_B$, $M_B$, and $M_G$, factors for hollow straw in the *B* genom of *T. persicum* var. stramineum, the *B* genom of the spelt series and the *G* genom of *T. Timopheevi* respectively; $O_D$, a factor for hollow straw in the *D* genom of the spelt series. The reactions of the different factors are given as follows: the hollow straw factor in the *A* genom is hypostatic to the *M* factors; the hollow straw factor of the *G* genom of *T. Timopheevi* gives intermediate heterozygotes with the *M* factors; the *M* factors are incompletely dominant over $M_B$ ; $O_D$ is epistatic to the *M* factors.

The influence of environmental factors on the expression of solidness in the vulgare type solid stemmed wheats used in this investigation have been studied by Platt (9). It was found that the expression of this character varied from station to station and from season to season. Solidness was favoured by long hours of sunshine in June, scanty rainfall and high temperatures. Widely spaced plants were more solid than closely spaced plants and moderate artificial shading inhibited the expression of solidness.

*Experimental*

In the present study the inheritance of the solid stem character was studied in the crosses Renown × S-615-9, Renown × S-633-3 and Thatcher × S-615-11.

The culms of $F_1$ plants of all crosses were found to be partially hollow.

An attempt was made to classify the main culm of each $F_2$ plant as hollow, intermediate or solid. However, in 1939 when the $F_2$ was grown, environmental conditions were such as to inhibit partially the expression of solidness. This was shown by the reaction of the parental plants, many of which were not entirely solid. As a result it was not possible to distinguish between solid and almost solid or hollow and almost hollow plants. Different types of intermediates were encountered and it was noted that the number of hollow-stemmed plants greatly exceeded the number of solid-stemmed ones. It was assumed that the solid stem represented the recessive condition and that such plants could be expected to breed true in the $F_3$ . It was not feasible to test the breeding behaviour of all $F_2$ plants. From an economic standpoint the hollow-stemmed plants were of no value. Consequently it was decided to grow in the $F_3$ all $F_2$ plants that were solid or that approached the solid condition. The number of $F_3$ lines that bred true for solidness would represent the number of $F_2$ plants that were actually solid-stemmed. In 1940 when these lines were grown conditions were favourable for the expression of solidness and the solid-stemmed lines could be determined without difficulty. The results obtained are presented in Table 2. In all cases the ratio of hollow and intermediate types to solid types fitted the 63 to 1 ratio satisfactorily. These results show that in these crosses 3 factor pairs are involved in the inheritance of solid stems.

In addition to the $F_3$ lines referred to above a number were grown from unselected $F_2$ populations. Despite the fact that conditions were favourable for the expression of solidness it was not considered advisable to classify individual plants with a view to determining the frequencies of $F_3$ lines exhibiting the various types of segregation. In the first place

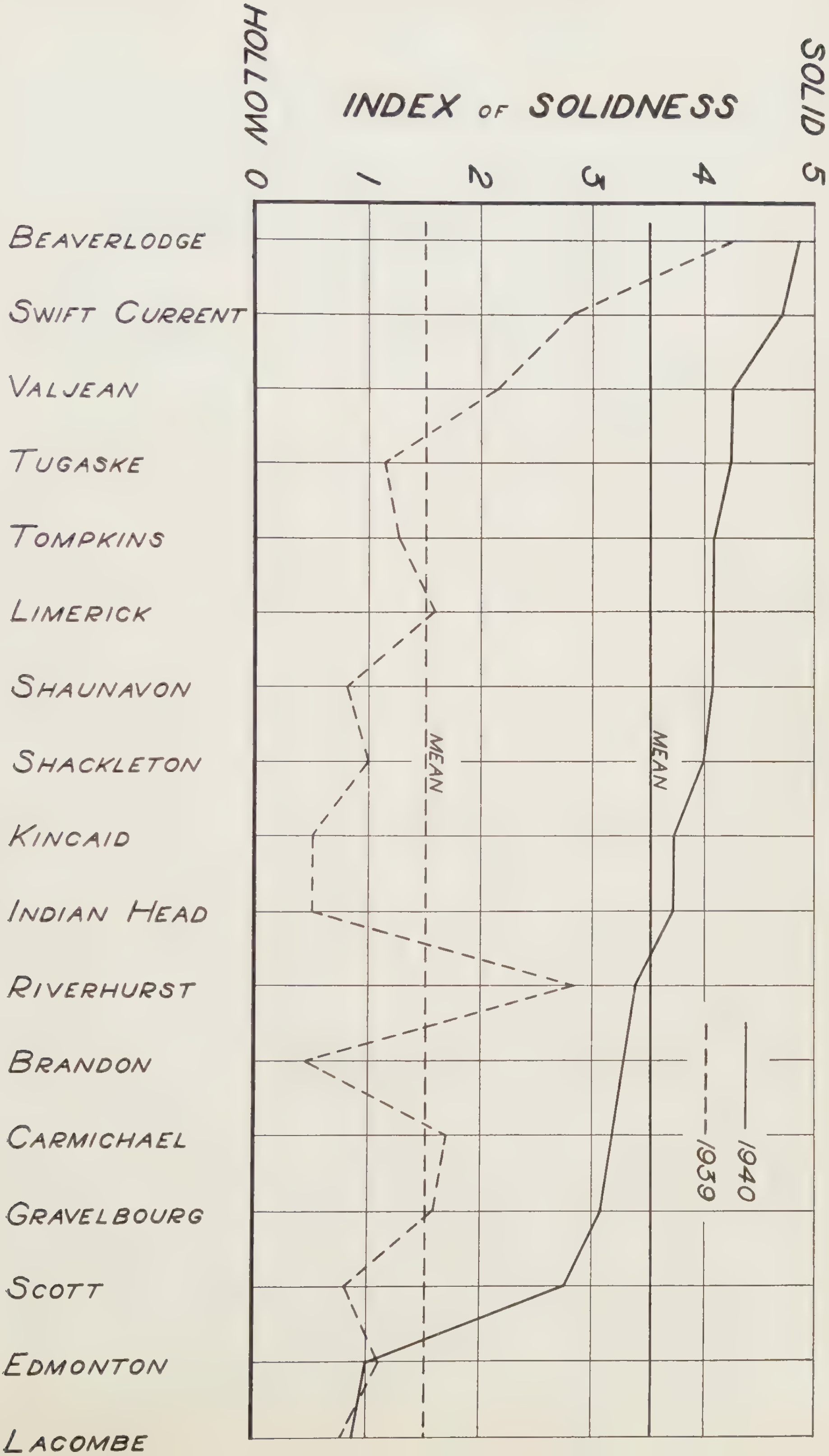
INDEX OF SOLIDNESS
0 HOLLOW
1
2
3
4
SOLID 5
BEAVERLODGE
SWIFT CURRENT
VALJEAN
TUGASKE
TOMPKINS
LIMERICK
SHAUNAVON
SHACKLETON
KINCAID
INDIAN HEAD
RIVERHURST
BRANDON
CARMICHAEL
GRAVELBOURG
SCOTT
EDMONTON
LACOMBE
MEAN
MEAN
1939
1940

TABLE 2.—THE BREEDING BEHAVIOUR OF WHEAT CROSSES FOR SEVERAL CHARACTERS AND TESTS OF GOODNESS OF FIT

| Cross | Numbers and generation | Observed | Calculated | $X^2$ | P lies between |
|---|---|---|---|---|---|
| Stem solidness. Expected ratios $F_2$ 63H* and I : 1So. $F_3$ 10H : 53 seg. and I : 1So. | | | | | |
| Renown × S 615 9 | 1727 $F_2$ plants | 1705 : 22 | 1699.7 : 27.0 | 0.94 | 0.3 and 0.5 |
| × | 173 $F_3$ lines | 20 : 149 : 4 | 27.0 : 143.1 : 2.7 | 2.68 | 0.2 and 0.3 |
| Renown × S 633 3 | 791 $F_2$ plants | 781 : 10 | 778.7 : 12.4 | 0.46 | 0.3 and 0.5 |
| × | 90 $F_3$ lines | 15 : 72 : 3 | 14.0 : 74.2 : 1.4 | 1.97 | 0.3 and 0.5 |
| Thatcher × S 615 11 | 843 $F_2$ plants | 835 : 8 | 829.7 : 13.2 | 2.06 | 0.1 and 0.2 |
| × | 158 $F_3$ lines | 26 : 131 : 1 | 24.7 : 130.8 : 2.5 | 0.97 | 0 5 and 0.7 |
| Stem rust. Expected ratio $F_3$ 1R : 2 seg. (3R : 1S) : 6 seg. (4 seg. 13S : 3R and 2 seg. 3S : 1R) : 7S | | | | | |
| Renown × S 615 9 | 594 $F_3$ lines | 39 : 72 : 224 : 259 | 37.1 : 74.2 : 222.8 : 259.9 | 0.17 | 0.95 and 0.98 |
| × | 942 $F_3$ plants† | 640 : 302 | 706.5 : 235.5 | 25.04 | <0.01 |
| × | 3113 $F_3$ plants‡ | 2301 : 812 | 2464.5 : 648.5 | 52.07 | <0.01 |
| Renown × S 633 3 | 246 $F_3$ lines | 15 : 38 : 93 : 100 | 15.4 : 30.8 : 92.2 : 107.6 | 2.24 | 0.5 and 0.7 |
| × | 541 $F_3$ plants† | 401 : 140 | 405.8 : 135.2 | 0.23 | 0.5 and 0.7 |
| × | 1379 $F_3$ plants‡ | 1018 : 361 | 1091.7 : 287.3 | 23.88 | <0.01 |
| Thatcher × S 615 11 | 293 $F_3$ lines | 20 : 22 : 119 : 132 | 18.3 : 36.6 : 109.9 : 128.2 | 6.86 | 0.1 and 0.05 |
| × | 381 $F_3$ plants† | 286 : 95 | 285.7 : 95.3 | 0 | <0.99 |
| × | 1994 $F_3$ plants‡ | 1559 : 435 | 1578.6 : 415.4 | 1.17 | 0.2 and 0.3 |
| Awning. Expected ratios. $F_2$ 3 awnletted : 1 awned. $F_3$ 1 awnletted : 2 seg. : 1 awned | | | | | |
| Renown × S 615 9 | 2614 $F_2$ plants | 1932 : 682 | 1960.5 : 653.5 | 1.66 | 0.1 and 0.2 |
| × | 356 $F_3$ lines | 90 : 188 : 78 | 89.0 : 178.0 : 89.0 | 1.93 | 0.3 and 0.5 |
| Thatcher × S 615 11 | 630 $F_2$ plants | 460 : 170 | 472.5 : 157.5 | 1.32 | 0.2 and 0.3 |
| × | 158 $F_3$ lines | 46 : 70 : 42 | 39.5 : 79.0 : 39.5 | 2.25 | 0.3 and 0.5 |
| Glume colour. Expected ratios $F_2$ 3 brown : 1 white. $F_3$ 1 brown : 2 seg. : 1 white | | | | | |
| Renown × S 615 9 | 1727 $F_2$ plants | 1286 : 441 | 1295.2 : 431.8 | 0.26 | 0.5 and 0.7 |
| × | 393 $F_3$ lines | 113 : 196 : 84 | 98.2 : 196.4 : 98.2 | 4.28 | 0.1 and 0.2 |

* Symbols: H = Hollow; I = Partially hollow; So = Solid; R = Resistant; S = Susceptible.
† From segregating $F_3$ lines having a preponderance of resistant plants.
‡ From segregating $F_3$ lines having a preponderance of susceptible plants.

there were a certain number of borderline plants that could not be definitely classified. Secondly, studies on environmental effects (9) that have been referred to suggested that the classification of individual plants might introduce serious sources of error. For example, a weak plant in a row might be shaded by its more vigorous neighbours and have its expression of solidness modified. As a result, these $F_3$ lines were classified as hollow, as solid or as intermediate and segregating.

The results obtained are presented in Table 2. The fits to a postulated ratio of 10 hollow to 53 intermediate and segregating to 1 solid are satisfactory. The 10 hollow is arrived at by assuming that of the 6 possible dominant genes, any 4, 5 or 6 will give the hollow condition. The pre-

ponderance of 10 hollow to 1 solid might not exist under all conditions. It is conceivable that under especially favourable circumstances hollow lines having only 4 or 5 dominant genes would show some solidness.

The results as a whole clearly show that 3 factor pairs are involved in the inheritance of solid stem in these crosses, with the solid stem condition being expressed only in plants having these factors in a recessive condition. It is suggested that the factors are cumulative in nature and that under normal conditions 4 or more dominant genes will produce phenotypically hollow plants.

## STEM RUST

The reaction to stem rust *(Puccinia graminis tritici)* was studied in the $F_3$ of the crosses Renown × S-615-9, Renown × S-633-3, Thatcher × S-615-11 and Thatcher × S-633-23. The natural epidemic that allowed for this study was not particularly severe but in all cases plants of the susceptible parents were heavily infected. A few small lesions were found on most plants of the resistant parents. The $F_3$ lines were classified as resistant, segregating, or susceptible. The number of individual resistant or susceptible plants within each segregating line was noted. No difficulty was experienced in classifying the lines but difficulty was encountered in classifying some individual plants, as scattered plants were found that approached more or less closely the condition found in the resistant varieties. As such plants might be later in maturing, the system of classifying all plants susceptible that showed any more infection than the resistant parent may have been in error.

Three of the crosses, Renown × S-615-9, Renown × S-633-3 and Thatcher × S-615-11 behaved in a similar manner and will be discussed together, while the fourth cross, Thatcher × S-633-23, behaved differently. It will be discussed later.

In each of the three former crosses about one-sixteenth of the lines were resistant and the segregating lines were of two types: in one type susceptible plants predominated while in the other resistant plants predominated. The reverse ratios suggest the action of an inhibitor. Therefore it is postulated that the resistant varieties carry a dominant factor for resistance and the susceptible varieties an inhibitor. The numbers obtained and the tests of goodness of fit are presented in Table 2. The agreement between the observed and the calculated in the case of the $F_3$ lines is very good in two of the crosses, but only fair in the third. In 3 out of 6 cases, however, the observed number of resistant and susceptible plants in the segregating lines does not agree with the expected. In two of these instances the disagreement is due to an excess of susceptible plants and in the other instance to an excess of resistant plants.

Neatby and Goulden (8) obtained the same type of segregation from the cross H-44-24 × Reward. Postulating the same hypothesis as outlined above they failed to obtain a satisfactory fit with the $F_3$ lines studied. The poor fit was due to an excess of resistant and a deficiency of susceptible lines. The fit was improved but still not satisfactory when a loose linkage between the factor for resistance and the allelomorph of the inhibitor was assumed. In this case there was an excess of segregating lines with susceptible plants predominant and a deficiency of susceptible lines.

The two types of segregation among $F_3$ lines found in this study are strong evidence for the presence of an inhibitor. It is suggested that some factor other than the genic complex of the parental varieties was influencing the results both in this experiment and in that reported by Neatby and Goulden. In the present study this factor might be inaccuracy in classification.

In the fourth cross, Thatcher × S-633-23, an entirely different situation was found. In a total of 467 $F_3$ lines, 434 were susceptible, 32 were segregating and one was resistant. Instances similar to this where apparently several genetic factors are involved have been reported by Neatby and Goulden (8). The present results are rather surprising, however, because S-633-3, which apparently contains one inhibiting factor, and S-633-23, used in this cross, are sister selections from the original variety S-633 and are identical in all other observed characteristics. Evidently the original S-633 was heterozygous for stem-rust reaction.

## AWNING

In the two crosses studied, Renown × S-615-9 and Thatcher × S-615-11, the difference between the tip-awned condition of Thatcher and Renown and the fully awned condition of S-615-9 and S-615-11 was found to be monogenic. The data are presented in Table 2.

## GLUME COLOUR

Glume colour was studied in one cross, Renown × S-615-9. The difference between the white glumes of Renown and the brown glumes of S-615-9 was found to depend on one factor pair. The data are presented in Table 2.

## TESTS OF INDEPENDENCE OR ASSOCIATION

Chi-squared tests of independence or association were calculated from the $F_3$ data between stem solidness and rust reaction, awning and glume colour. The results are presented in Table 3. In the one cross, Renown × S-615-9, there is evidence of association between stem solidness and awning. There is no evidence of such an association in the other cross, Thatcher × S-615-11, whose factors for stem solidness and awning appear to be similar. No satisfactory explanation for these results can be suggested. There is no evidence of association between stem solidness and rust reaction or glume colour.

TABLE 3.—$X^2$ TEST OF INDEPENDENCE OR ASSOCIATION BETWEEN STEM SOLIDNESS AND OTHER CHARACTERS IN THE $F_3$ OF CERTAIN WHEAT CROSSES

| Stem solidness and | Renown × S-633-3 | | Renown × S-615-9 | | Thatcher × S-615-11 | |
|---|---|---|---|---|---|---|
| | $X^2$ | P lies between | $X^2$ | P lies between | $X^2$ | P lies between |
| Rust reaction | 4.17 | 0.7 and 0.5 | 11.54 | 0.05 and 0.1 | 0.63 | >0.99 |
| Awning | — | — | 12.74 | 0.01 and 0.02 | 1.30 | 0.8 and 0.9 |
| Glume colour | — | — | 5.12 | 0.2 and 0.3 | — | — |

## DISCUSSION

The object of the breeding program of which this study is a part is the production of new wheats having solid stems, resistance to stem rust and other agronomically desirable characteristics. The results of this investigation suggest that there are no insurmountable obstacles that preclude obtaining such wheats. However, they do suggest that real difficulties are likely to be experienced. With stem solidness controlled by three, and rust reaction by two or more genetic factors, very large populations will have to be grown in order to obtain reasonable numbers of solid stemmed, rust resistant lines. The portion of such lines that can be expected to have the many other attributes of a desirable wheat variety awaits the results of further investigation.

## SUMMARY

The inheritance of stem solidness, stem rust reaction, awning and glume colour was studied in segregating generations of crosses involving Renown and Thatcher as hollow-stemmed, stem rust resistant, awnletted, white-chaffed parents and S-615-9 and S-615-11 as solid-stemmed, stem rust susceptible, awned, brown-chaffed, and S-633-3 and S-633-23 as solid-stemmed, stem rust susceptible, awnletted, white-chaffed parents.

In the crosses Renown × S-615-9, Renown × S-633-3 and Thatcher × S-615-11 stem solidness was found to be controlled by three factor pairs with the solid stem condition being expressed only in plants having these factors in a recessive condition. It is suggested that the factors are cumulative in nature and that four or more dominant genes will produce phenotypically hollow plants.

It was tentatively concluded that stem rust reaction was governed by a dominant factor for resistance and an inhibitor in the crosses Thatcher and S-615-11, Renown × S-615-9 and Renown × S-633-3. In the cross Thatcher × S-633-23 several factors appeared to be involved as only one resistant $F_3$ line in a total of 467 was found.

Awning in the crosses Renown × S-615-9 and Thatcher × S-615-11 and glume colour in the cross Renown × S-615-9 were, in each case, monogenic.

Stem solidness and awning were associated in the cross Renown × S-615-9 but not in the Thatcher × S-615-11 cross. Neither stem rust reaction nor glume colour was associated with stem solidness.

## ACKNOWLEDGMENTS

The authors are indebted to Dr. L. H. Newman, Dominion Cerealist, Central Experimental Farm, Ottawa, for his assistance in planning this project. Mr. L. B. Thomson, Superintendent, Dominion Experimental Station, Swift Current, placed certain facilities at our disposal and his enthusiasm and encouragement were much appreciated. Mr. Carl Fraser, Chief Assistant Cerealist, Central Experimental Farm, Ottawa, placed facilities at our disposal for making the crosses and Dr. R. F. Peterson, Senior Assistant Agricultural Scientist, Dominion Rust Research Laboratory, Winnipeg, kindly criticized the manuscript. Mr. J. B. Dore, Plot Foreman at this Station, assisted materially with the field work.

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# CULTURAL STUDIES WITH BARLEY. I.

## DIFFERENTIAL RESPONSES OF VARIETIES TO DATE OF SEEDING WITH RESPECT TO YIELD[1]

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### INTRODUCTION

In barley production the important objectives from the point of view of producer and consumer are yield and malting quality. Yield obviously is of major importance anywhere. The importance of malting quality depends to a large extent upon locality. In some regions and areas good quality malting barley can not be produced because of climatic limitations, just as good bread wheat can not be produced in some regions for the same reason. Manitoba is one of the principal sources of malting barley in the Dominion of Canada. Therefore both yield and malting quality are of prime importance here.

Cultural practices generally in vogue in Manitoba are not conducive to the attainment of the maximum in either yield or quality. Wheat is the most important crop in the province. It therefore receives the greater care and attention. It is sown upon the best land, and since early seeding is one of the more important steps in the attainment of high yields among all of our small grain crops, it is sown first. Barley seeding is usually delayed until all wheat seeding has been completed, and since barley is frequently sown upon second choice land, seeding is often further delayed in order that extra spring tillage may be given to assist in the control of weeds. Under these circumstances it is not strange that so little barley has been graded higher than 3 C.W. Six Row, and that the portion entering export channels should at times have the reputation of being exceedingly dirty.

The effects of various cultural practices on both yield and malting quality have received a great deal of attention on the part of European workers and extensive studies have been reported by Russell and Bishop (3). The results are mainly applicable to local conditions. They show a great deal of variation between different cultural practices, especially fertilizer treatment. However the accumulated data point to the general conclusion that early seeding is advisable for the production of malting barley. From the point of view of Manitoba investigators the most important lesson taught by the European work was the fact that differential responses to various cultural practices are large and important. These results forewarned investigators of the necessity of designing experiments in such a way that the differential effects and responses could be accurately measured.

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[1] Contributions from the Division of Plant Science, the University of Manitoba. Published as Paper 191 of the Associate Committee on Grain Research.
[2] Professor of Plant Science.
[3] Biochemist, Associate Committee on Grain Research, Division of Plant Science.
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[5] Research Assistant, Division of Plant Science.

In 1935 experiments were started[1] at the University of Manitoba with the object of studying the responses of several different varieties to different dates and rates of seeding, fertilizer treatments, and crop sequences. These were conducted at four stations. On account of hail, rust and drouth of varying intensity as affecting the different stations, only limited data were obtained. The experiments were continued through 1936. Beginning with 1937 the plan and design was modified somewhat for the purpose of attaining greater precision. In that form it was continued without interruption by the present senior author and his associates through 1939 when it was concluded. It is mainly with the data for the 3-year period 1937–39 that this series of papers deals, though incidental reference is made to the 1936 data.

The cultural practices involved in the entire investigation as finally designed were (1) date of seeding, (2) rate of seeding, and (3) fertilizer treatment. Three varieties were used and attention to the differential response of these varieties was stressed. The studies dealt with the effects of these cultural practices on yield and malting quality. The most significant feature of the experiments was not the study of the separate factors, but the fact that each was studied in relation to the other.

The present paper, the first in the series, deals with yield response only. Moreover it deals with yield response to date of seeding only, stressing the differential response of the three varieties to this feature. The response from the point of view of malting quality, and the yield response to the other cultural practices will be dealt with in succeeding papers.

## MATERIALS AND METHODS

Since the experiment involved simultaneous study of all of the cultural practices the entire plan will be laid out here. A factorial design was used so that each level of each factor could be studied at each level of each of the other factors. The same design was used at each of 4 stations. This plan made it possible to study, with the same degree of precision, the differences between different levels of the separate cultural factors, and also the major interactions between them. The fact that 4 well distributed stations and 3 years were involved obviously provided for study of the interactions between cultural practices and environment.

### *Varieties*

The varieties used were O.A.C. 21, Mensury Ottawa 60, and Gartons. These are the 3 principal varieties grown for malting purposes in Manitoba[2]. O.A.C. 21, the standard of malting quality under the Canada Grain Act, is a 6-rowed rough-awned barley, with blue aleurone. It is of the Manchurian type as are also the other two varieties. Mensury Ottawa 60 is closely similar to O.A.C. 21 in all its characters. Both of these varieties are highly susceptible to rust. Gartons is also a 6-rowed rough-awned type. It is not a pure variety as evidenced by a constant admixture of blue with the predominating yellow aleurone grains. It has distinctly weaker

[1] The experiments were started by Dr. G. P. McRostie, formerly Head of the Department of Agronomy, University of Manitoba, now Head of the Department of Field Husbandry, Ontario Agricultural College.

[2] It has recently been announced that Gartons will not be eligible for grades higher than 3 C.W. six-row after Aug. 1, 1942.

straw than the other 2 varieties and possesses a fair degree of rust resistance. It has been popular for a number of years in certain important barley areas, particularly in that known as the Portage Plains, since it has seemed to fit better into the system of culture of that area, which has generally called for relatively late seeding.

*Stations*

The 4 stations were Winnipeg (the University of Manitoba), Carman, Newdale, and Swan River. Winnipeg represents the Red River Valley area. Carman is about 50 miles southwest of Winnipeg, Newdale about 180 miles northwest, and Swan River about 325 miles northwest of Winnipeg. The latter station is near the northern limit of arable land in Manitoba, and represents a fairly large area adapted to the production of high quality malting barley.

*Seasons*

Differences between seasons were considerable as is shown in Appendix A which presents the temperature and precipitation data. These features will be discussed in connection with the interpretation of the experimental results. An important feature of the seasonal conditions was the severe rust epidemic during the years 1937 and 1938. There was practically no rust during 1936 and 1939.

*Dates of Seeding*

The dates of seeding were spaced about 2 weeks apart. The plan was to bring the first seeding as close to May first as possible, or having in mind seasonal differences, as close as possible to the time when wheat seeding became general. The dates were not the same at all stations. In most cases the seeding was done in rotation by the same crew. The following are the dates at each of the stations for each of the years.

*Seeding dates 1937*

| | First date | Second date | Third date |
|---|---|---|---|
| Winnipeg | May 7 | May 19 | June 1 |
| Carman | 6 | 18 | 1 |
| Newdale | 13 | 26 | 8 |
| Swan River | (crop a complete failure) | | |

*Seeding dates 1938*

| | | | |
|---|---|---|---|
| Winnipeg | May 11 | May 24 | June 4 |
| Carman | 4 | 18 | 2 |
| Newdale | 11 | 23 | 6 |
| Swan River | 13 | 24 | 8 |

*Seeding dates 1939*

| | | | |
|---|---|---|---|
| Winnipeg | May 1 | May 12 | May 28 |
| Carman | 4 | 16 | 29 |
| Newdale | 6 | 18 | 31 |
| Swan River | 8 | 20 | June 6 |

### Appendix A.—Meteorological data

| Year | Winnipeg | | | | | Newdale (Minnedosa) | | | | | Carman (Morden Exp. Sta.) | | | | | Swan River | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp., F. | | | Prec. | Rel. of prec. to normal | Temp., F. | | | Prec. | Rel of prec. to normal | Temp., F. | | | Prec. | Rel. of prec. to normal | Temp. F., | | | Prec. | Rel. of prec. to normal |
| | Mean | Max. | Min. | | | Mean | Max. | Min. | | | Mean | Max. | Min. | | | Mean | Max. | Min. | | |
| 1936 | | | | | | | | | | | | | | | | | | | | |
| May | 57.5 | 93 | 29 | 0.94 | −1.25 | 55.8 | 90 | 26 | 0.75 | −1.03 | 60.2 | 97 | 27 | 0.55 | −1.64 | | | | | |
| June | 60.8 | 92 | 33 | 2.41 | −0.67 | 59 3 | 91 | 35 | 2.06 | −0.92 | 63.4 | 102 | 38 | 2.70 | −0.56 | | | | | |
| July | 75.5 | 108 | 43 | 1.87 | −1.20 | 72.5 | 107 | 41 | 0.40 | −2.09 | 77.4 | 111 | 46 | 0.75 | −2.34 | | | | | |
| Aug. | 66.4 | 102 | 42 | 0.50 | −1.84 | 63.1 | 97 | 35 | 1.00 | −1.13 | 67.5 | 102 | 40 | 2.25 | +0.57 | | | | | |
| 1937 | | | | | | | | | | | | | | | | | | | | |
| May | 55.2 | 87 | 24 | 2.20 | +0.01 | 53.4 | 82 | 19 | 2.76 | +0.98 | 55.6 | 91 | 26 | 1.70 | −0.49 | | | | | |
| June | 62.4 | 90 | 36 | 2.32 | −0.76 | 59.3 | 91 | 30 | 4.07 | +1.09 | 63.6 | 97 | 36 | 5.48 | +2.22 | | | | | |
| July | 69 6 | 92 | 45 | 2.83 | −0.24 | 66.7 | 96 | 41 | 1.55 | −0.94 | 70.6 | 97 | 48 | 6.89 | +3.80 | | | | | |
| Aug. | 69.4 | 97 | 45 | 2.12 | −0.22 | 65.2 | 97 | 40 | 2.34 | +0.21 | 70.0 | 98 | 42 | 0.43 | −1.25 | | | | | |
| 1938 | | | | | | | | | | | | | | | | | | | | |
| May | 52 | 79 | 27 | 1.9 | −0.29 | 50 | 78 | 24 | 1.1 | −0.68 | 53 | 80 | 29 | 1.5 | −0.69 | | | | 2.2 | |
| June | 62 | 93 | 39 | 1.3 | −1 78 | 59 | 87 | 30 | 1 6 | −1.38 | 63 | 95 | 35 | 2.2 | −1.06 | 61 | 90 | 34 | 1.8 | |
| July | 69 | 93 | 48 | 4.1 | +1.03 | 67 | 95 | 40 | 1.0 | −1.49 | 70 | 96 | 49 | 4.3 | +1.21 | | 89 | 40 | 3 0 | |
| Aug. | 68 | 93 | 41 | 1.4 | −0.94 | 65 | 92 | 38 | 1.8 | −0.33 | 69 | 95 | 41 | 1.9 | +0.22 | | | | 5.3 | |
| 1939 | | | | | | | | | | | | | | | | | | | | |
| May | 56 | 94 | 22 | 1.4 | - 0.79 | 55 | 88 | 22 | 2.5 | +0.72 | 58 | 95 | 26 | 1.8 | −0.39 | 52 | 86 | 20 | 1.2 | |
| June | 59 | 86 | 37 | 2.5 | −0.58 | 56 | 79 | 28 | 2.3 | −0.68 | 60 | 87 | 37 | 3.8 | +0.54 | | | | | |
| July | 70 | 100 | 35 | 1.4 | −1 67 | 68 | 93 | 40 | 2.6 | +0.11 | 73 | 103 | 39 | 0.6 | −3.03 | 66 | 92 | 42 | 5.4 | |
| Aug. | 68 | 94 | 46 | 5.5 | +3.16 | 65 | 97 | 35 | 2.3 | +0.17 | 69 | 100 | 43 | 4.1 | +2.42 | | | | | |

Season characteristics:

1936—Abnormally high July temperature. Precipitation much below normal.

1937—Temperatures moderate or normal all stations. No serious moisture deficiency. Newdale, abundant precipitation except July; Carman, heavy precipitation June and July; only slightly subnormal in May.

1938—Temperature moderate. Dry June all stations. Newdale, dry throughout the season.

1939—Winnipeg, May and July dry; Newdale, normal or nearly so throughout season. Carman, very dry July, responsible for failure of crop under latest sowing.

*Rates of Seeding*

Rates of seeding were 1 bu. $1\frac{3}{4}$, and $2\frac{1}{2}$ bushels per acre. The most common rate prevailing in Manitoba is $1\frac{1}{2}$ to $1\frac{3}{4}$ bushels. The rates adopted may therefore be classified as light, medium and heavy.

*Fertilizer Treatment*

Fertilizer recommendations in this province generally stress phosphate. Some nitrogen is usually included in order to stimulate early seedling growth. Potassium is not included. The usual practice, which was followed in this experiment, is to apply the fertilizer in drills at the time of seeding. The treatments compared were (1) no treatment, (2) 96 lb. of 16–20–0, and (3) 40 lb. 11–48–0. It will be apparent that the two fertilizer applications provided for equal amounts of phosphate ($P_2O_5$), while the 96-pound rate applied much more nitrogen than the 40-pound rate.

*Design of Experiment*

The factorial 3 × 3 × 3 × 3 design (3 varieties, 3 rates, 3 dates, and 3 fertilizer treatments) chosen for this experiment was furnished by Dr. C. H. Goulden, Senior Cerealist, Dominion Laboratory of Plant Pathology, Winnipeg. As pointed out earlier, it provided for the simultaneous study of each level of each factor at every level of each of the other factors. Taking any one variety as a starting point, for the purpose of illustration, that variety was sown at 3 dates; on each of these dates it was sown at 3 rates; at each rate the 3 fertilizer treatments were compared. These combinations called for 27 plots; each combination appeared on 3 replicates making a total of 81 plots. There were 3 varieties. Therefore the grand total of plots at each of the 4 stations was 243.

In laying out the experiment in the field the trial area was first divided into 3 large sections, 1 for each date of seeding. From a practical standpoint this was an obvious starting point. Each of these sections was subdivided into 3 blocks, 1 for each replication series of the 27 cultural combinations. Since this is too large a number to lay out in a block unit without extensive replication of such large units, further subdivision was necessary. To accomplish this, and still conserve the comparisons for all major factors and the simple interactions between them, the 27 cultural combinations were divided into 3 sets of 9 each. In each of these sets the 3 varieties, 3 rates of seeding, and 3 fertilizer treatments were compared. Each variety was compared at each rate of seeding, and the fertilizer treatments were superimposed upon these combinations according to the cyclic system described by Fisher (1) and Goulden (2). Each of these 3 sets of 9 cultural combinations was randomized within each of 3 respective sub-blocks. Each set or sub-block was replicated 3 times, appearing once in each of the 3 blocks or replication series. This will be clear on reference to Figure 1 which is a detailed diagram of one of the 3 large date sections into which the experimental field at each station was first divided as described above. The key immediately below the figure will serve to identify the individual plot treatments which are coded within the diagram.

| | | |
|---|---|---|
| 111 | 311 | 232 |
| 233 | 332 | 113 |
| 331 | 133 | 131 |
| 132 | 222 | 223 |
| 313 | 231 | 312 |
| 322 | 323 | 211 |
| 212 | 213 | 122 |
| 221 | 112 | 333 |
| 123 | 121 | 321 |

| | | |
|---|---|---|
| 123 | 121 | 113 |
| 233 | 332 | 122 |
| 132 | 222 | 312 |
| 212 | 133 | 232 |
| 111 | 231 | 131 |
| 221 | 112 | 223 |
| 331 | 213 | 321 |
| 322 | 311 | 333 |
| 313 | 323 | 211 |

| | | |
|---|---|---|
| 221 | 332 | 211 |
| 132 | 133 | 321 |
| 123 | 112 | 113 |
| 322 | 323 | 122 |
| 331 | 222 | 232 |
| 111 | 213 | 333 |
| 233 | 231 | 131 |
| 212 | 121 | 312 |
| 313 | 311 | 223 |

FIGURE 1. Plot layout for first Seeding Date. Swan River, 1937.

Key:

| *Varieties* | *Rates* | *Fertilizer* |
|---|---|---|
| 1 ——. O.A.C. 21 | —1—. 1 bu. | ——1. No fertilizer |
| 2 ——. Gartons | —2—. $1\frac{3}{4}$ bu. | ——2. 96 lbs. 16-20-0 |
| 3 ——. Mensury | —3—. $2\frac{1}{2}$ bu. | ——3. 40 lbs. 11-48-0 |

To assist the reader in decoding the diagram it will be sufficient to point out that the application of the key to the plot in the upper left hand corner of the diagram, which carries the number 111, discloses that this was sown to the variety O.A.C. 21 at the rate of 1 bu. per acre, and received no fertilizer.

TABLE 1.—AVERAGE YIELDS OF VARIETIES IN BUSHELS PER ACRE WITHIN STATION, DATES AND YEARS

| Station | Date | O.A.C. 21 | | | | Mensury | | | | Gartons | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1937 | 1938 | 1939 | Mean | 1937 | 1938 | 1939 | Mean | 1937 | 1938 | 1939 | Mean |
| Winnipeg | First | 43.1 | 43.8 | 56.6 | 47.8 | 42.2 | 41.9 | 56.7 | 46.9 | 33.0 | 45.9 | 43.5 | 40.8 |
| | Second | 47.0 | 23.7 | 48.8 | 39.9 | 45.2 | 23.9 | 43.1 | 37.4 | 36.7 | 41.0 | 39.7 | 39.2 |
| | Third | 18.3 | 11.3 | 42.5 | 24.0 | 17.9 | 10.4 | 43.6 | 24.0 | 40.4 | 33.8 | 40.3 | 38.2 |
| Carman | | | | | 2 yr. 3 yr. | | | | 2 yr. 3 yr. | | | | 2 yr. 3 yr. |
| | First | 40.3 | 40.7 | 29.4 | 40.5 36.8 | 35.4 | 39.9 | 28.2 | 37.7 34.5 | 45.0 | 46.8 | 31.7 | 45.9 41.2 |
| | Second | 34.0 | 21.6 | 11.8 | 27.8 22.5 | 28.4 | 21.0 | 11.1 | 24.7 20.2 | 37.8 | 33.8 | 10.0 | 35.8 27.2 |
| | Third | 15.2 | 9.8 | — | 12.5 — | 12.1 | 7.9 | — | 10.0 — | 31.0 | 16.6 | — | 23.8 — |
| Newdale | First | 24.0 | 30.7 | 22.3 | 25.7 | 21.8 | 29.5 | 25.1 | 25.4 | 25.1 | 27.6 | 20.9 | 24.5 |
| | Second | 20.4 | 25.2 | 22.2 | 22.6 | 18.9 | 25.2 | 19.0 | 21.0 | 24.3 | 30.8 | 21.5 | 25.5 |
| | Third | 13.1 | 21.3 | 21.4 | 18.6 | 11.2 | 18.9 | 21.6 | 17.2 | 21.5 | 26.5 | 20.5 | 22.8 |
| Swan River | First | | 39.0 | 48.0 | 43.6 | | 39.7 | 47.2 | 43.5 | | 39.2 | 49.5 | 44.4 |
| | Second | | 46.0 | 50.7 | 48.4 | | 45.3 | 47.1 | 46.3 | | 52.3 | 50.8 | 51.6 |
| | Third | | 25.9 | 59.7 | 42.7 | | 21.0 | 56.7 | 38.8 | | 59.5 | 54.8 | 57.1 |

The diagram in Figure 2 shows the complete layout at each station, omitting the sub-divisions into the 9 plots in each of the sub-blocks.

At all stations, and in each year the plots were laid out on summer-fallow. Each individual plot consisted of 7 rows $18\frac{1}{2}$ feet long and spaced 6 inches apart. In harvesting, the 2 outside rows were discarded and the ends trimmed according to the usual practice with rod rows.

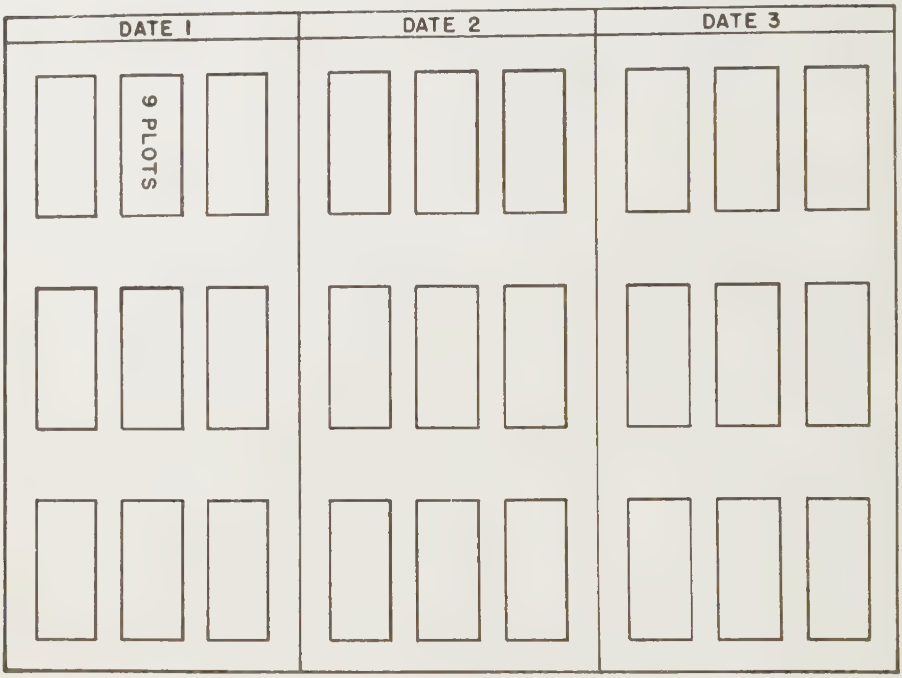


FIGURE 2. Plan of complete field layout.

## RESULTS AND DISCUSSION

The data with which this paper deals are presented in summarized form in Table 1. Within each of the 4 stations the yields are shown by years for each date of seeding for each variety, and finally the 3-year mean for each date is shown in the column at the right of each variety section. All of the values appearing in this table are means over all other treatments. For example, the value of 56.6 for O.A.C. 21, first date of seeding, Winnipeg, 1939, represents the mean yield for all seeding rates, and all fertilizer treatments for that date. This value is the mean of 27 individual plot yields. Its derivation is shown in Table 2.

The data for varieties and dates have been summarized further in Figure 3, which consists of a family of histograms arranged in tabular form. The columns of histograms show the yields for the different varieties and the means over all varieties. The rows of histograms represent the yields for each of the stations and the means over all stations. Each individual histogram consists of 3 columns representing the 3 dates of seeding.

TABLE 2.—SAMPLE DERIVATION OF THE INDIVIDUAL YIELD VALUES APPEARING IN TABLE 1

| Variety | Rate of seeding | Rate of fertilizer | Replicates | | | Means | General mean |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | | |
| O.A.C. 21 | 1 bu. | 0 | 57.6 | 38.6 | 48.6 | 48.3 | |
| | | 96 lb. | 87.1 | 76.2 | 46.2 | 69.8 | |
| | | 40 lb. | 56.6 | 55.0 | 63.9 | 58.5 | 58.9 |
| | 1¾ bu. | 0 | 55.4 | 39.3 | 51.0 | 48.6 | |
| | | 96 lb. | 61.0 | 57.5 | 58.4 | 59.0 | |
| | | 40 lb. | 31.1 | 62.1 | 62.6 | 51.9 | 53.2 |
| | 2½ bu. | 0 | 39.0 | 45.8 | 57.0 | 47.3 | |
| | | 96 lb. | 56.7 | 66.3 | 41.7 | 54.9 | |
| | | 40 lb. | 67.4 | 62.1 | 85.4 | 71.6 | 57.9 |
| | | | | | | | 56.6 |

From left to right the dates are: first date, second date, and third date. The histograms are coded by means of a scale of yields at the left of the figure, the base line representing 5 bushels per acre. They provide for comparison of mean yields between dates and between varieties, and also for ready comparison of the effect of delayed seeding upon individual varieties at each station.

*Average Effects of Date of Seeding*

The effect of date of seeding was very definite. This is shown in the histogram in the lower right hand corner of Figure 3, which represents the mean yields for dates over all varieties, stations and years. It is apparent at once that yield decreased progressively with lateness of seeding. Comparisons within and between the individual histograms show, however, that this statement is a broad generalization with some exceptions. It is not substantiated at all of the stations, and the fact stands out rather sharply that the varieties differ as regards the relative decreases with later seeding. It is necessary, therefore, to consider the effect of date of seeding in relation to the different varieties, and at the different stations, in order to obtain a true picture of the factors involved.

*Differential Responses of Varieties to Date of Seeding*

The first 3 histograms at the bottom of Figure 3 show the mean yields of each variety for each of the dates. These means include the data for all stations. All varieties show progressively decreasing yields with delayed seeding, but the patterns of the varieties differ. It is actually more correct to say that the pattern for Gartons differs sharply from those of O.A.C. 21 and Mensury, these two resembling each other closely. While the difference between the first and third dates for O.A.C. 21 and Mensury was 15.0, the corresponding difference for Gartons was only 3.5 bushels.

As was pointed out earlier, Gartons is moderately resistant to rust, while O.A.C. 21 and Mensury are highly susceptible. It might be concluded that the difference in reaction to delayed seeding can be accounted

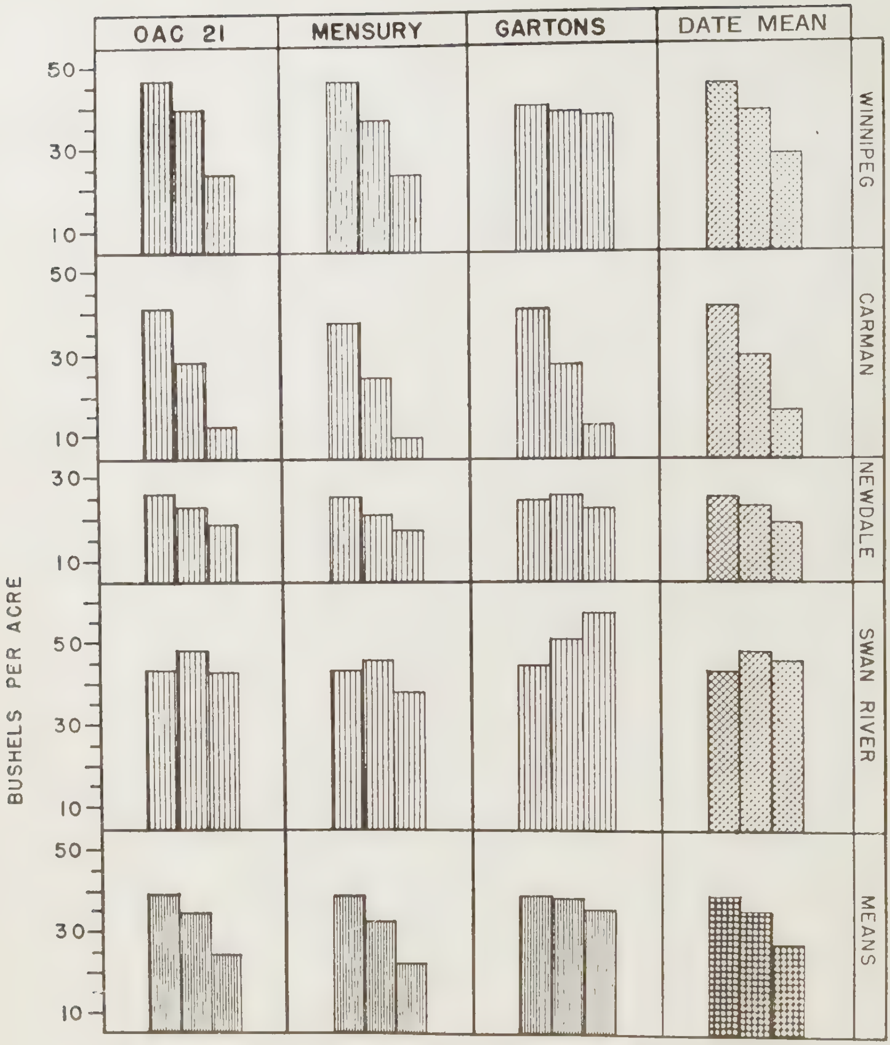


FIGURE 3. Histograms for mean yields over 3 years, illustrating the differential effects of dates of seeding and stations on varieties. The columns in each histogram represent 3 consecutive dates of seeding, starting at the left with the first date.

for by that fact since 2 of the years involved in the experiment were rust years. That conclusion is only partially correct, however, as will be pointed out later.

The general statement that delayed seeding decreases yield holds true for all the varieties. The facts are equally susceptible of an interpretation expressed by the alternative statement, namely, that varietal comparisons change with delayed seeding. This is important from the academic viewpoint as the changes render the differentiation of varieties impossible if the mean yields over all dates are considered. If one wishes to define a high or low yielding variety one must compare the varieties within dates, and then limit the definition by references to an appropriate

date range. A practical aspect of these facts is that advice as to choice of variety is more frequently sought than advice as to date of seeding. Obviously, if these 3 varieties were involved, the recommendations would change with the advance of the season. Moreover it is useful to know, in case of seeding failure, that some variety or varieties may be sown at a later date with reasonable hope of a crop, though somewhat diminished in yield and quality. Gartons appears to be such a variety.

According to these results one would recommend early seeding and the choice of either O.A.C. 21 or Mensury. The similarity between them in yield behaviour is obvious and indeed they have been found to resemble each other very closely in all characters throughout this investigation. Although there is very little difference between them and Gartons at the first date they have a number of other advantages including malting quality. At the second date Gartons is somewhat superior and at the third date definitely so. For seeding in late May, therefore, Gartons is easily the first choice.

*Interaction between Environment and Date of Seeding*

The right hand column of histograms above the general mean in Figure 3 shows the mean yields at each station for each of the 3 seeding dates. Comparisons of these provide striking evidence that the effects of delayed seeding are modified by environment. The greatest decrease in yield occurred at Carman and the least at Newdale. At Winnipeg it was intermediate between these two. At Swan River the pattern was changed entirely, the lowest yield occurring at the first date and the highest at the second. Unfortunately only 2 years' data are included in the Swan River mean, the 1937 crop having been destroyed by hail. However, the more detailed examination and discussion of the data presented in the next section will leave scarcely any doubt that the Swan River response was actually quite different from that at any of the other stations.

*Triple Interaction between Variety, Date of Seeding and Environment*

In the 12 histograms in the section of Figure 3, at the left of the extreme right hand column and above the bottom row, the yields are shown for each variety, at each seeding date and at each of the 4 stations. At 3 stations, Winnipeg, Carman and Newdale, the general trend of successive reductions in yield from the first to the third date was observed for the 2 varieties O.A.C. 21 and Mensury. Gartons showed this trend at two stations, Winnipeg and Carman, and, as observed in comments on the mean yields, the decreases for Gartons were less than those for the other varieties, especially at Winnipeg. At the latter station Gartons showed very little reduction from date to date; only 2 bushels from first to third date. At Carman the reduction was marked although somewhat less than those for O.A.C. 21 and Mensury. At Newdale Gartons produced a slightly higher yield at the second date than at the first, but decreased at the third in common with other varieties.

At Swan River the patterns of all variety-date histograms were strikingly different from the corresponding ones at any of the other stations. The difference between the O.A.C. 21-Mensury behaviour and the Gartons behaviour within the station was also especially pronounced. In the case

of O.A.C. 21 and Mensury the highest yield was produced at the second seeding date and the lowest at the third. Gartons, on the other hand, showed a progressive and sharp increase from the second through the third date. The difference in general behaviour between this station and the others may be ascribed to differences in climatic conditions but that does not explain the distinctive behaviour of Gartons. It must be considered to be quite different from the other varieties in some physiological factor or factors.

From the above analysis it develops that, while the generalization that delayed seeding is accompanied by reduced yields still holds in a broad way, there are notable exceptions. These exceptions consist mainly of the variety Gartons, which does not suffer uniformly from delayed seeding, and the northern station, Swan River, where none of the varieties show the unfavourable reaction to delayed seeding that is typical of the 3 more southerly stations which presumably are more representative of the province.

*Differential Effects of Seasons*

The data for the individual years are summarized in Table 3 to show the effects of seasons on dates of seeding at the different stations. It will be observed that there are some variations from the general trend of reduced yield with delayed seeding. These are confined to 2 stations, namely Winnipeg and Swan River. At Winnipeg only the 1937 results show deviations from the average trend. The second date out-yielded the first by 3.6 bushels in that year. This can hardly be regarded as a serious deviation, in view of the magnitude of the differences between the first and third dates, or the second and third dates. The data for Swan River

Table 3.—Annual and mean yields in bushels per acre, by dates over all varieties and treatments

| Station | Date | 1937 | 1938 | 1939 | Mean |
|---|---|---|---|---|---|
| Winnipeg | 1 | 39.4 | 43.9 | 52.3 | 45.2 |
| | 2 | 43.0 | 29.5 | 43.9 | 38.8 |
| | 3 | 25.5 | 18.5 | 42.1 | 28.7 |
| | Mean | 36.0 | 30.6 | 46.1 | 37.6 |
| Carman | 1 | 40.2 | 42.5 | 29.8 | 41.4* |
| | 2 | 33.4 | 25.5 | 11.0 | 29.4* |
| | 3 | 19.4 | 11.4 | | 15.4* |
| | Mean | 31.0 | 26.5 | | 28.7* |
| Newdale | 1 | 23.6 | 29.3 | 22.8 | 25.2 |
| | 2 | 21.2 | 27.1 | 20.9 | 23.1 |
| | 3 | 15.3 | 22.2 | 21.2 | 19.6 |
| | Mean | 20.0 | 26.2 | 21.6 | 22.6 |
| Swan River | 1 | | 39.3 | 48.2 | 43.8* |
| | 2 | | 47.9 | 49.5 | 48.7* |
| | 3 | | 35.5 | 57.1 | 46.2* |
| | Mean | | 40.9 | 51.6 | 46.2* |

* Mean over two years.

are distinctly different as between the 2 years, as well as being different from the average over all stations. The highest yield in 1938 was obtained from the second date and in 1939 there was a progressive increase from the first through the third date. It must be concluded that conditions at Swan River are quite different from those in the major portion of the rest of the province.

The data discussed in the previous paragraph are the means over all varieties and show the average effects of seasons. Table 1 may now be examined for any smaller variations from the general trend of the means. At Winnipeg in 1937 O.A.C. 21 and Mensury produced their highest yields from the second date of seeding, but both varieties decreased progressively from early to late seeding during the other 2 years. Gartons resembled the other two varieties in its behaviour in 1938 only. In 1937 its behaviour was quite different, with its maximum yield at the third date, and in 1939 while the first was the optimum date, as in the case of the other varieties, there was no progressive reduction, and only a slight difference between any of the dates. At Carman progressive decreases with delayed seeding were observed in all years for all varieties though Gartons differed somewhat from the others in degree of change. At Newdale where the average reduction was smaller than at the other stations the behaviour pattern was closely similar as between all 3 years as regards both O.A.C. 21 and Mensury. There was a progressive decrease from date to date with minor variations, e.g. Mensury 1939. Gartons showed this tendency only in 1937. In 1938 and 1939 the second date was optimum, although in 1939 the differences between dates were so small in the case of all of the varieties that Gartons can not be said to have differed significantly in behaviour from the other two. At Swan River there was greater variation as between the 2 years as regards the behaviour of O.A.C. 21 and Mensury, than at any of the other stations. The second date was decidedly optimal in 1938 and the last date in 1939 for both varieties. In the case of Gartons the last date was optimal in both years.

As suggested earlier, the pronounced difference in reaction between Gartons and the other 2 varieties in response to date of seeding may be interpreted in the sense that varietal comparisons change with date of seeding. The data in Table 1 show that when comparisons were made within years and stations at Winnipeg and Newdale, O.A.C. 21 was superior at its most favourable date (and closely followed by Mensury) to Gartons at its most favourable date in the majority of cases. At Carman Gartons was consistently superior, and at Swan River honors were divided as between O.A.C. 21 and Gartons.

This analysis of the data for the individual years does not in any way alter the general conclusions already drawn. Early seeding, that is seeding close to May first may be expected to return the most satisfactory yields throughout most of Manitoba. In the northern portion, or in the area represented by Swan River, it appears to be advisable to delay seeding until well into the latter half of May. The further recommendation may be made that either O.A.C. 21 or Mensury be the variety chosen. Although the differences in their favour were not large in all cases, and indeed were consistently in favour of Gartons at the one station Carman, the other

varieties have other advantages, especially malting quality, that make such recommendations sound. Where it is necessary to seed late, Gartons is definitely to be preferred.

*Relation of Rust and Meteorological Conditions to the Results*

As suggested earlier, the differential response of the varieties to date of seeding may be accounted for in part by differences in rust reaction. Gartons has a good deal of resistance to stem rust, while O.A.C. 21 and Mensury are highly susceptible. During 1937 and 1938 severe stem rust epidemics prevailed and the latter 2 varieties rusted badly at all stations. Gartons suffered much less. Severe damage to the susceptible varieties was confined to the crops sown at the later dates. The yields resulting from the first seeding suggest that little if any damage was done even to the crop from the susceptible varieties when sown at that date. This is a highly important point when considering date of seeding. However rust reaction does not furnish the entire answer.

The year 1939 was not a rust year. Nevertheless, differential response was maintained in that year although reduced in degree. This will be apparent on reference to Table 1. However, comparison of 1 non-rust with 2 rust years does not provide a convincing argument. For that reason there are introduced the pertinent data from the preliminary experiment made in 1936, a rust-free year. They are presented in the form of a family of histograms in Figure 4. Data are available from 3 stations only,

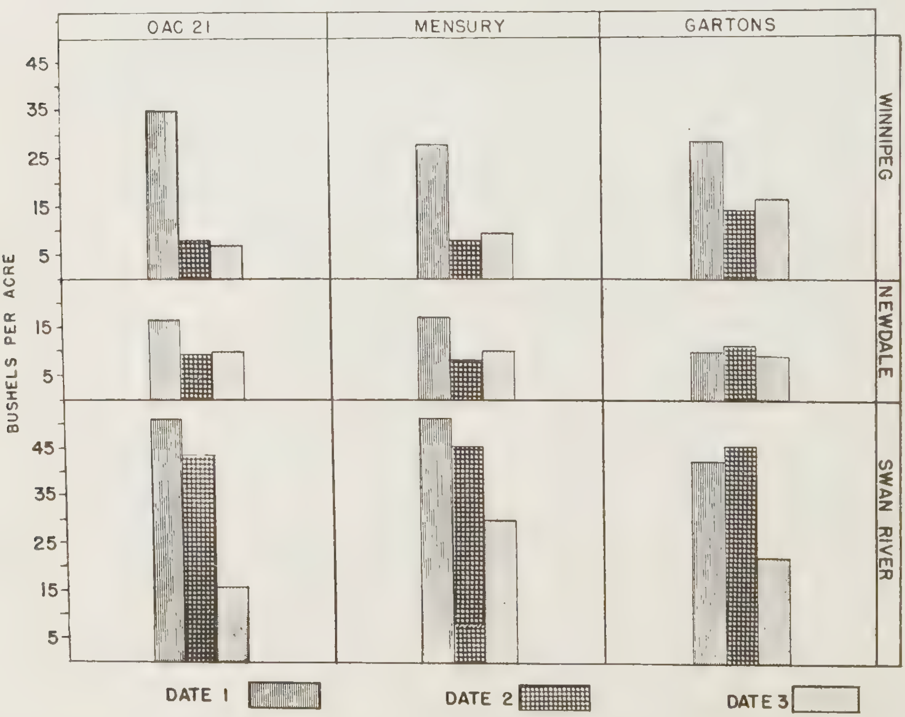


FIGURE 4. Histograms for mean yields for 1936 only, illustrating the differential effects of dates of seeding and stations on varieties. The columns in each histogram represent 3 consecutive dates of seeding, starting at the left with the first date.

owing to crop failure at Carman. These histograms show again that there was a differential response of varieties to date of seeding, and confirm the conclusion that differences in rust reaction do not account for all of the differential response of varieties to dates of seeding, and other important influencing factors must therefore have been operating as well.

In 1936 the soil moisture conditions in Winnipeg were fair, those at Newdale poor. and those at Swan River good. These facts no doubt account for the fair and good yields at Winnipeg and Swan River, respectively, from the first date of seeding, and for the poor yields at Newdale from that date. However, that season, as reference to the appendix table of meteorological data will show, was very dry at all stations with high temperatures during the growing season, and these would account for the very low yields from the last 2 dates of seeding at Winnipeg and Newdale. The depletion of soil moisture to a critical stage did not occur at Swan River owing to its high initial content and to lower temperatures than in the south. Carman suffered a crop failure in that year as already pointed out. Despite the drouth conditions in the south Gartons showed less variation in yield between dates than the other varieties. It may be repeated that rust was not a factor in that result.

The 1937 season was quite different from that of 1936, and as already noted, it was a rust year. Soil moisture conditions and the temperatures during the growing season were reasonably favourable, so that the low yields of the susceptible varieties in that year may be attributed in a large measure to damage by rust.

The heavy rust epidemic in 1938 was probably again a large factor contributing to the low yields from the later dates of seeding, especially the third date at Winnipeg and Carman. However, dry conditions prevailed at all stations in June. At Newdale, July also was dry. The effect of the June drouth must have been considerable in reducing the yields from the 2 later dates of seeding at the southern stations.

In 1939 conditions varied considerably as between stations. Although the season was somewhat unfavourable at Winnipeg good yields were obtained. At Newdale moisture conditions were relatively favourable although June rainfall was somewhat lower than usual. At Carman July was very dry and the temperatures abnormally high. These conditions were no doubt largely responsible for the very low yields for all varieties from the second seeding date and for the total failure of the crop at the third date. At all stations, with the exception of Carman, Gartons, despite the absence of rust, showed less variation than the other varieties in the effect of delayed seeding, indicating again that there were other differences between Gartons and the other varieties besides differences in rust reaction.

## STATISTICAL ANALYSES

The data for each station were subjected to separate analyses of variance by the appropriate procedure (1, 2). The results of these analyses for the factors discussed in this paper are given in Table 4. These data show that the mean squares due to differences between varieties, though relatively large, are not significantly greater than the greatest mean square affecting differentiation of varieties. That is, considerable differences

between varieties were demonstrated, but these differences varied at different levels of the other factors. This is shown by the magnitudes of the mean squares due to interactions between varieties and dates, and between varieties, dates and years. In other words, although comparisons of varieties over all dates failed to demonstrate significant differences between them, comparisons within dates did show significant differences. It is also interesting to note that the mean squares due to difference between dates varied from station to station.

Table 4.—Analyses of variance

| Variance due to | Degrees of freedom | Mean squares | | | |
|---|---|---|---|---|---|
| | | Fort Garry | Carman[1] | Newdale[2] | Swan River[2] |
| Varieties | 2 | 656.5 | 1954.8 | 86.3 | 2939.0 |
| Dates | 2* | 16729.6 | 24537.6 | 753.5 | 984.7 |
| Years | 2 | 14985.6 | 12517.4 | 2581.5 | 14052.0 |
| V × D | 4 | 3024.8+ | 2.0 | 215.6 | 1239.7 |
| V × Y | 4 | 3244.1+ | 447.4 | 241.6 | 2681.5 |
| D × Y | 4 | 2809.6+ | 1675.0 | 382.2 | 4132.5 |
| V × D × Y | 8 | 653.5++ | 125.2++ | 107.0+ | 2255.0++ |
| Error | 432 | 32.3 | 9.5 | 18.0 | 30.6 |

++ Significantly greater than mean square due to greatest error affecting differentiation.
Single signs denote that 5% level of significance is attained.
Double signs denote that 1% level of significance is attained.
* Not comparable, as it is impossible to separate mean effect of dates and effect of blocks. Comparisons are possible between dates within other factors.
[1] Only two dates, i.e. 1 D. F. for dates other d. f. change accordingly.
[2] Only two years, i.e. 1 D. F. for years other d. f. change accordingly.

The application of these data has already been discussed and need not be elaborated in this section. From the mean squares, those interested in specific comparisons may derive necessary differences by the customary procedure.

## SUMMARY

An investigation to determine the effect of cultural practices on the yield of 3 varieties of barley, namely O.A.C. 21, Mensury Ottawa 60, and Gartons is discussed. The factors studied were date of seeding, rate of seeding and fertilizer treatments. The effect of 3 levels of each of these factors on each variety was studied simultaneously by means of an experiment of factorial design. The tests were conducted at each of 4 stations for 3 consecutive years, 1937, 1938, and 1939. A preliminary experiment had been conducted in 1936. This paper presents the results for dates of seeding only.

Two of the varieties, O.A.C. 21 and Mensury Ottawa 60, were closely similar in behaviour and response under all conditions. Gartons, on the other hand, showed a reaction that was radically different. Early seeding produced the highest yields under most of the conditions studied and in general there was a reduction in yield from the earliest to the latest date. The reduction in yield of Gartons, however, was very much less than that of the other two varieties. O.A.C. 21 produced the highest yields under early seeding at most of the stations with Mensury a close second, but Gartons took first rank by a wide margin under late seeding.

The behaviour of all varieties was quite different at the northernmost station (Swan River) from that at the other three. At that station delayed seeding produced higher yields than early seeding.

The results indicate that variety recommendations would differ for different conditions. In general O.A.C. 21 is the most suitable variety for early seeding, the soundness of that recommendation being enhanced by its superior malting quality as compared with Gartons. If delayed seeding is necessary for the purpose of weed control or for any other reason, the use of Gartons may be expected to entail less sacrifice of yield than either of the other 2 varieties.

The differential response of the varieties was in part due to the difference in rust reaction. Gartons is moderately resistant to rust, and the other 2 varieties highly susceptible. The years 1937 and 1938 were severe rust years and the differential was greater during those years. However, the general pattern of behaviour in 1936 and 1939, which were non-rust years, was similar to that during the other 2 years. Early seeding appeared to be insurance against rust damage since even the susceptible varieties suffered no appreciable reduction in yield under the earliest seeding.

## ACKNOWLEDGMENTS

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# PASTURE STUDIES XXII.

## DRY MATTER DEFECATION AS AN INDEX OF FORAGE INTAKE BY GRAZING STEERS[1]

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In a review of the literature on pasture research up to 1929, Shuster (12) lists 13 methods of approach to the problem. Since that time more precise methods of measurement of the comparative value of agronomic treatments have been evolved. Measurement of rates of growth or botanical reaction, under manurial treatments, can be obtained with a considerable degree of accuracy. But attempts to measure nutritive value of pasture herbage have met with many difficulties.

Manual sampling of pasture plots by mowing, clipping or even plucking cannot, on theoretical grounds alone, be expected to simulate actual grazing with any certain degree of accuracy (4, 5, 9). Accepted chemical methods of separating the "nutritive fractions" do not enhance the picture. These fractions are not chemical entities and vary in composition with the source and nature of the herbage. Furthermore, chemical description of pasturage has not proved to be a reliable index of nutritive value as represented by gains in weight of grazing animals (3).

Biological methods have been proposed to incorporate the grazing animal factor in the test. Early trials consisted of the use of such measurements as "pasture days" or "cow days". These may be of some value under range experiments or mass survey conditions as a gross means of comparison, but they can be of little value in precise work in restricted experimental trials on small plots, with a limited number of animals.

Vinal (13) has suggested the use of a term "unit days of grazing" as a measure of carrying capacity. In doing this he has used fractional "units" for animals of various ages, from 25% of a unit for young calves to 95% for the 3-year-olds. This was perhaps a refinement over the unrestricted use of "pasture days" for comparative purposes, but it still does not take into consideration the variation in appetite or enterprise or feeding capacity noticeable in otherwise similar grazing animals. Garrigus (5) has shown feed intake by freely grazing animals to be independent of any detectable characteristics of the animals.

Feeding trials or grazing trials have been conducted by a large number of workers. A simple, frequently used measurement in such studies is the total gain of the animals on the experimental areas. As this is one of the practical criteria of the value of pasture, it might appear to be a useful way of measuring the comparative value of pasture amendments. However, definite limitations are imposed on generalizations from the resultant data. To overcome these limitations the American Society of Agronomy in 1934 accepted the method of measuring the yield of plots in terms of the Total

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Digestible Nutrients apparently provided according to feeding standard requirements for maintenance and gains, or milk production of the grazing animals, with or without a comparison with protected plots mowed to measure the quantity of herbage "consumed" or available. An average digestibility of dry matter of 72% was suggested (14). Knott, Hodgson and Ellington (8), in attempting to correlate calculated Total Digestible Nutrient values obtained from grazed and clipped plots, have met with little success. Robinson, Pierre and Ackerman (11), obtained an average of 19% higher yields of Total Digestible Nutrients from plots (using Eckles and Gullickson standards) by clipping than by grazing. There was a wide variation from year to year, caused by uncontrollable changes in the botanical composition of the pasture. Within years, however, they found a very high correlation between yields calculated from grazing and from clipping permanent plots. They conclude that: "although the yields obtained by clipping permanent plots cannot be converted directly into yields in terms of grazing units, they have been a very effective measure of the relative increases in yields resulting from various lime and fertilizer treatments." Jones, Ewalt and Haag (7), in using dairy cattle in rotational grazing obtained, by the American Society of Agronomy method, only 75% of the calculated Total Digestible Nutrients obtained from clipped plots. However, Brandt and Ewalt (1) subsequently obtained 95% of the calculated yield of Total Digestible Nutrients from clipped plots. The difference was due to a difference in pasture growth and the distance the cows had to travel to pasture.

Such variations in results suggest that clipping methods cannot be relied on to measure the nutritive value to the grazing animal of pasture herbage.

Also, the use of average coefficient of digestibility, or average maintenance requirements, in the calculation of Total Digestible Nutrient yield may introduce appreciable errors. Morrison's coefficients of digestibility for immature and mature fresh grasses are based on but two and four digestion trials respectively (6). Brown (2) shows that a 15% difference in calculated pasture yield occurs when Eckles' Total Digestible Nutrients standard and Armsby's Thermal unit are used, due to a difference in emphasis on maintenance and gain requirements. Thus stocking plots to different degrees would affect the result when using such standards. A factor, which may make the use of average digestibility values unreliable, is the seasonal change which takes place in pasture herbage, a change in physical and chemical composition which may affect its digestibility.

Garrigus (5) has used a means of studying productivity of pasture plots without the use of feeding standard tables. The method is based on the entirely reasonable assumption that the ratio of dry matter consumed to that defecated by a grazing steer will be practically constant, provided that source of the dry matter consumed is roughage of uniform species, stage of maturity and chemical composition. If, therefore, the consumption-defecation ratio for a given steer can be determined, his dry-matter intake may be calculated from data on dry matter defecated.

In a direct comparison of the usual clipping method to determine consumption with that of calculating the feed intake from faecal output,

Garrigus found a discrepancy of 57%. The forage consumption of a steer according to his faecal output was, during an 8-day period, 192% of his maintenance requirement as compared to a calculated 83% shown by the clipping method.

## EXPERIMENTAL PROCEDURE (1940 SEASON)

Although Garrigus employed short periods of grazing it seemed quite possible to adapt the general principle of his method to full season grazing studies. Preliminary work was started early in June, 1940. Of the three acres of land obtained for this investigation, one was set aside to be grazed by steers fitted with faeces collection bags.

Two steers obtained through the co-operation of Canada Packers, Montreal, were placed on the 1-acre plot of indigenous grass on June 24th. Being strange to the area and to the electrified fence, it was found necessary to tether them for a period of 15 days. After this the animals were allowed the freedom of the pasture area.

On July 3, a canvas harness and rubberized collection bag were fitted to one steer. Similar harness and bag were fitted to the second steer on July 23; because of galling, it was removed for a day and replaced without subsequent trouble. From then to September 21, the harness was removed only for brushing of the animals. Bags were changed twice each day and the weight of faeces obtained. Some loss of faeces was encountered occasionally for the first 2 weeks, partly because of defecation while lying down, and partly because the steers were inclined at first to squeeze the bags as they lay down. A piece of sheet rubber, long enough to go well down into the bag and wide enough to cover the pin bones, with a hole near the top so that it could be slipped over the tail, helped materially to prevent these losses.

The pasture herbage was quite mature when the animals were placed on the plot. It consisted of a mixture of timothy, red top, and small amounts of alsike, sweet clover, and purple vetch (*Vicia cracca*), all in flower by July 1. Couch grass patches and Kentucky blue grass had already formed seed. For this reason one-half of the plot was mown and the hay removed. In this way new young grass was soon available. It proved to be more acceptable so that by mid-July it was found necessary to mow the mature growth from the other half of the plot. From this time to late August the pasture was sufficient to permit gains in weight by the steers, but they began to go short of feed early in September. By the time the trial was terminated the herbage did not meet their maintenance requirements.

A stall feeding period was included from September 6, to September 12. Fresh grass, as free from weeds as possible, was mown from areas adjoining the pasture and fed to the animals twice each day. Water was before them at all times. The steers were fed all that they would take without waste.

## RESULTS

The design of this trial demanded conditions as nearly natural as possible for the grazing steers. Thus certain factors, which in usual animal trials are easily kept under control or do not appear at all, had to receive

attention in this test. For example, trials of 15 days such as Garrigus has run, with daily changes of plots, have no seasonal trends in supply or in digestibility of herbage to interfere with the interpretation of results.

*Seasonal Trends*

Data collected in this preliminary trial showed a pronounced seasonal trend for each steer. (Figure 1). It can be seen from the graph that the trends are not quite parallel for the two steers. At least two factors may affect these trends, digestibility and available herbage. It was very noticeable that the "red" steer was the more enterprising of the two and this can account for the apparently greater "availability" of feed during the latter part of August and early September.

In digestibility trials a constant level of intake is established during the pre-collection period, assuming that under a uniform environment, food residues will pass through the animal at a constant rate. A digestibility trial conducted at this station by Lange (10) on dried pasture herbage shows this to be true with a coefficient of variability of 4.2% in daily output of faecal dry matter. Since the dry matter intake was constant in amount, the faeces output should have been constant. Actually the daily output deviated from the mean by .632 ± .354 pounds.

In the present test the daily intake was not constant, as shown by the curve of dry matter output. Assuming, however, that the digestibility of the dry matter eaten remained unchanged during the period involved, the trend of faeces output as obtained by fitting polynomial values to the observations (See Figure 1) may be taken as the "expected" dry matter excretion corresponding in a sense to the average output of a test when

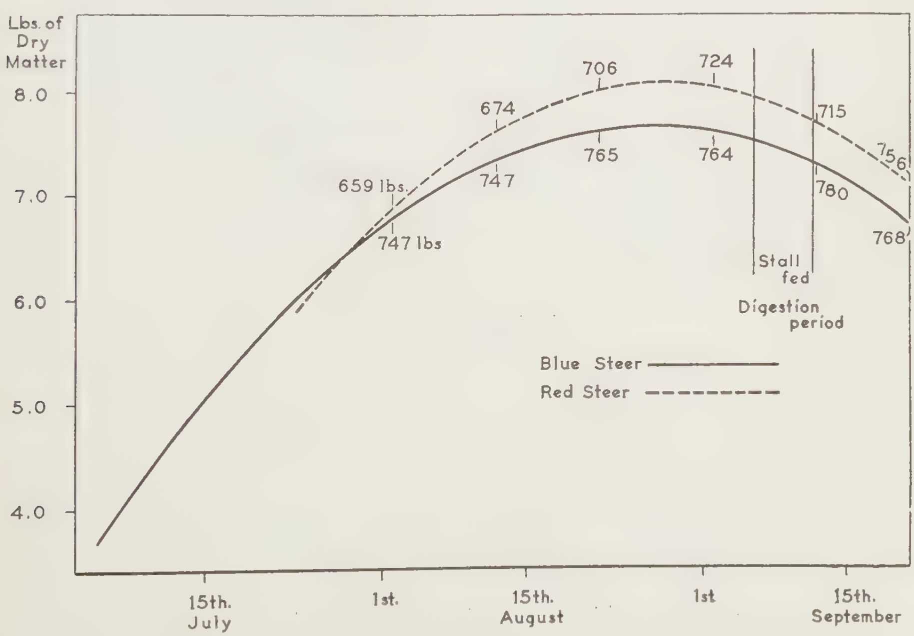


FIGURE 1. Seasonal Trend in Faecal Output (dry matter) 2nd degree polynomial. Figures on graph are weights of steers.

intake is constant. The mean deviation in daily faeces output from these "expected" values was found to be .690 ± .553 pounds. This figure agrees satisfactorily with that of .632 ± .354 pounds obtained in the trial by Lange mentioned above.

It seems evident that seasonal variation in intake of herbage is one major factor in governing the observed trend in faeces output, and that actual daily variation is not significantly greater than that encountered under controlled, uniform, stall feeding.

*Digestibility of Herbage*

In standard digestibility trials where total dry matter intake is kept as nearly constant as possible, the consideration of this lag is not important if a sufficient length of time is allowed for preliminary feeding. But where feed intake cannot be kept constant as in grazing tests, several questions arise. When other factors are kept constant, will the lag be consistent? In other words, can digestion coefficients be obtained without a preliminary feeding period by relating feed intake to the faecal output on a later day, the lag having been experimentally determined previously?

If the approximate length of time required for the passage of food residues through the animal could be established for a given animal, then, in pasture nutrition trials, periodic digestibility tests could be shortened and the need for an artificially limited intake eliminated.

Data from the digestion period included in this study indicate that there is a 4 to 5 day lag in the excretion of feed residues (Figure 2).

*Correlation Between Weight of Steer and Faeces Output*

In pasture trials it frequently has been assumed that gain in weight, herbage consumption, and weight of the animal are correlated. The use of the "animal unit" is based on this assumption. A study of the limited data from this preliminary trial supports the findings of Garrigus that size of steer has no consistent effect on rate of forage consumption (as measured by faecal output). From the available data a correlation between weight of steer and daily dry matter excretion of $r = .21$ was obtained, in contrast to a correlation of $r = .65$ between gain in weight and dry matter excretion. Neither of these correlations is statistically significant because of small number of observations. These relations, however, are clearly seen in Figure 1, when the heavier steer had the small faeces output and smaller. gains.

## CONCLUSIONS

The data from the herein reported tests suggest the following tentative conclusions.

1. The lack of correlation between size of animal and its response to pasture feeding makes the "animal unit" an unreliable basis of comparison for critical tests of the nutritive value of pastures.

2. A definite seasonal trend in faecal dry matter output can be established, and when this is taken into account the daily variation in faecal loss is not significantly greater than that of steers under a controlled, limited, feeding. Thus the use of faecal dry matter along with a measure of actual digestibility, will give an accurate picture of the true nutritive value of a pasture area, by the technique here outlined.

3. Size of animal is not correlated with intake as measured by dry matter excretion, whereas there is some indication that gains and dry matter excretion are correlated.

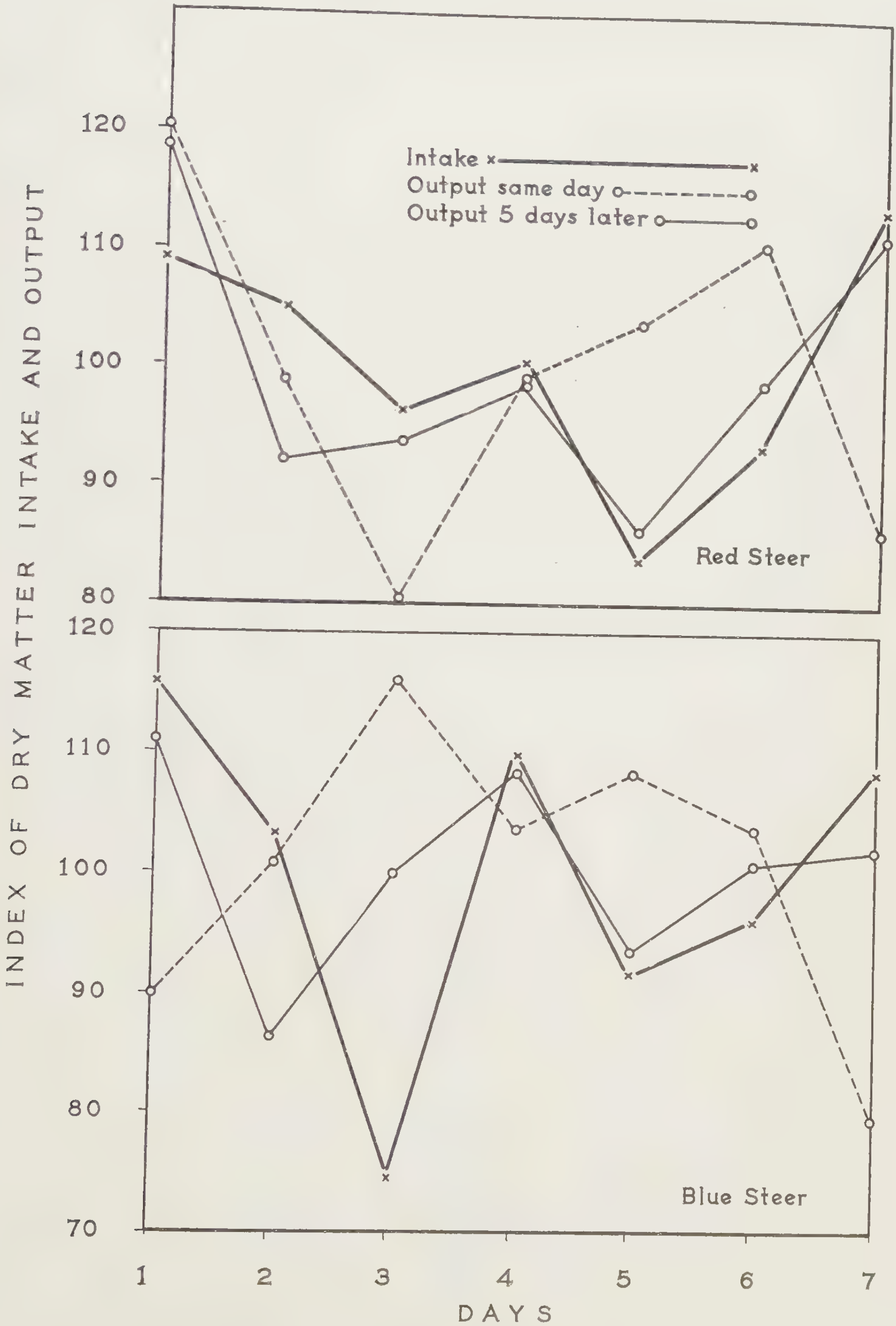


FIGURE 2. Trends of Dry Matter Intake.

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## APPENDIX TABLE 1

Observed daily faecal output and calculated output from 2nd degree polynomials (pounds dry matter)

| July | Blue Steer | | Red Steer | |
|---|---|---|---|---|
| | Observed | Calculated | Observed | Calculated |
| 5 | 3.6 | 3.63 | | |
| 6 | 3.4 | 3.79 | | |
| 7 | 4.8 | 3.93 | | |
| 8 | 4.7 | 4.08 | | |
| 9 | 4.3 | 4.22 | | |
| 10 | 4.3 | 4.36 | | |
| 11 | 3.8 | 4.50 | | |
| 12 | 4.4 | 4.63 | | |
| 13 | 4.4 | 4.76 | | |
| 14 | 3.8 | 4.89 | | |
| 15 | 5.1 | 5.01 | | |
| 16 | 5.4 | 5.13 | | |
| 17 | 5.7 | 5.25 | | |
| 18 | 5.7 | 5.37 | | |
| 19 | 6.0 | 5.48 | | |
| 20 | 5.9 | 5.60 | | |
| 21 | 5.5 | 5.71 | | |
| 22 | 4.6 | 5.81 | | |
| 23 | 5.6 | 5.91 | | |
| 24 | 6.3 | 6.01 | 5.0 | 5.90 |
| 25 | 6.7 | 6.11 | 6.6 | 6.02 |
| 26 | 6.2 | 6.20 | 6.9 | 6.14 |
| 27 | 6.2 | 6.29 | 6.7 | 6.26 |
| 28 | 7.2 | 6.38 | 7.9 | 6.38 |
| 29 | 6.5 | 6.46 | 6.7 | 6.48 |
| 30 | 6.7 | 6.54 | 7.3 | 6.58 |
| 31 | 5.5 | 6.62 | 5.5 | 6.68 |

## APPENDIX TABLE 1—Concluded

OBSERVED DAILY FAECAL OUTPUT AND CALCULATED OUTPUT FROM 2ND DEGREE POLYNOMIALS (POUNDS DRY MATTER)—*Concluded*

| July | Blue Steer | | Red Steer | |
|---|---|---|---|---|
| | Observed | Calculated | Observed | Calculated |
| August | | | | |
| 1 | 7.5 | 6.70 | 6.3 | 6.78 |
| 2 | 6.5 | 6.77 | 6.7 | 6.88 |
| 3 | 6.9 | 6.84 | 6.2 | 6.96 |
| 4 | 6.0 | 6.91 | 5.9 | 7.05 |
| 5 | 6.6 | 6.97 | 6.0 | 7.13 |
| 6 | 7.3 | 7.03 | 6.8 | 7.21 |
| 7 | 7.5 | 7.09 | 7.5 | 7.28 |
| 8 | 7.0 | 7.14 | 8.0 | 7.36 |
| 9 | 7.1 | 7.20 | 7.3 | 7.43 |
| 10 | 8.0 | 7.25 | 7.3 | 7.49 |
| 11 | 8.0 | 7.29 | 8.2 | 7.55 |
| 12 | 5.0 | 7.34 | 6.2 | 7.61 |
| 13 | 7.3 | 7.38 | 7.0 | 7.67 |
| 14 | 7.4 | 7.41 | 7.1 | 7.72 |
| 15 | 7.3 | 7.45 | 6.7 | 7.77 |
| 16 | 7.7 | 7.48 | 8.0 | 7.81 |
| 17 | 8.0 | 7.51 | 7.6 | 7.85 |
| 18 | 9.0 | 7.54 | 8.5 | 7.89 |
| 19 | 7.7 | 7.56 | 7.7 | 7.92 |
| 20 | 8.8 | 7.58 | 8.7 | 7.95 |
| 21 | 8.5 | 7.60 | 9.6 | 7.98 |
| 22 | 7.8 | 7.61 | 8.7 | 8.00 |
| 23 | 5.9 | 7.62 | 8.6 | 8.02 |
| 24 | 9.1 | 7.63 | 9.9 | 8.04 |
| 25 | 9.7 | 7.64 | 10.0 | 8.05 |
| 26 | 6.3 | 7.64 | 7.0 | 8.06 |
| 27 | 6.7 | 7.64 | 8.1 | 8.06 |
| 28 | 7.4 | 7.64 | 7.6 | 8.07 |
| 29 | 7.3 | 7.63 | 8.4 | 8.06 |
| 30 | 7.1 | 7.62 | 7.7 | 8.06 |
| 31 | 6.3 | 7.61 | 8.0 | 8.05 |
| September | | | | |
| 1 | 8.4 | 7.60 | 8.7 | 8.04 |
| 2 | 6.8 | 7.58 | 9.5 | 8.02 |
| 3 | 7.9 | 7.56 | 8.1 | 8.00 |
| 4 | 7.5 | 7.53 | 9.0 | 7.98 |
| 5 | 8.0 | 7.51 | 8.7 | 7.96 |
| 6 | 6.5 | 7.48 | 8.5 | 7.93 |
| 7 | 7.2 | 7.45 | 7.0 | 7.89 |
| 8 | 8.4 | 7.41 | 5.6 | 7.86 |
| 9 | 7.4 | 7.37 | 7.0 | 7.82 |
| 10 | 7.8 | 7.33 | 7.3 | 7.77 |
| 11 | 7.4 | 7.29 | 7.8 | 7.72 |
| 12 | 5.8 | 7.24 | 6.0 | 7.67 |
| 13 | 6.7 | 7.19 | 6.2 | 7.62 |
| 14 | 7.2 | 7.14 | 6.5 | 7.56 |
| 15 | 6.2 | 7.09 | 5.7 | 7.50 |
| 16 | 6.8 | 7.08 | 6.4 | 7.44 |
| 17 | 6.8 | 6.97 | 7.3 | 7.37 |
| 18 | 6.6 | 6.90 | 7.9 | 7.30 |
| 19 | 7.0 | 6.84 | 8.0 | 7.22 |
| 20 | 7.8 | 6.77 | 8.7 | 7.14 |
| 21 | 7.9 | 6.70 | 9.2 | 7.06 |

# DIGESTIBILITY STUDIES WITH RUMINANTS

## VIII. ASSOCIATIVE DIGESTIBILITY OF HAY AND GRAINS[1]

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Coefficients of digestibility of grains and concentrates are usually determined with a basal ration of roughage. In this paper a comparison has been made between coefficients so determined and coefficients determined when the grains and concentrates constituted the sole ration. Steers were used as experimental animals.

During 1938-39, digestion trials were conducted on 7 rations, namely, hay, barley, oats, oil cake, hay and barley, hay and oats, and finally, hay and oil cake. The experiment was originally set up in the form of a 7 × 7 randomized Latin square, using 7 animals in 7 periods. Feed refusals in several cases, however, prevented the completion of this square. In order to obtain more values, the experiment was carried through for a second year. For the original experiment, carried out in 1938–1939, 7 grade Shorthorn steers, designated A, B, C, D, E, F and G, were used. They were 3½ years old and averaged respectively, 637, 640, 588, 610, 605, 536 and 607 kilograms in live weight. Three of these, namely, B, F and G, were carried over to the second year (1939–40). A fourth animal, designated H, 2½ years old, was included in the experiment at this time. The weights of the animals respectively, for this second season were 693, 577, 651 and 551 kilograms.

The entire experiment comprised 14 periods, each of which included a 12-day preliminary period and a 12-day collection period. In one case, because of feed refusal, the collection period was 4 days; in one case, it was 6 days and in two cases, it was 8 days. During the second season, in the trials where grains alone were fed the preliminary period was reduced to 7 days. There was a total of 61 individual digestion trials in the entire experiment.

Table 1.—Botanical analysis of hay

| — | 1938–1939 | | 1939–1940 |
|---|---|---|---|
| | Top of mow | Lower in mow | |
| | % | % | % |
| Red and alsike clover | 72.6 | 75.8 | 62.0 |
| Alfalfa | 17.9 | 20.8 | 31.3 |
| Grass (timothy) | 7.9 | 3.2 | 5.7 |
| Weeds | 1.6 | 0.2 | 1.0 |

[1] Joint contribution from the Division of Chemistry, Science Service, and the Division of Animal Husbandry, Experimental Farms Service, Dominion Department of Agriculture, Ottawa.
[2] Chemist.
[3] Assistant-in-Chemistry.
[4] Laboratory Assistant-in-Chemistry.
[5] Dominion Agricultural Chemist.
[6] Dominion Animal Husbandman.

The botanical analyses of the hay are shown in Table 1. The barley and oats were grown at the Central Experimental Farm and were respectively "Ottawa Mensury" and "Victory" varieties. The oil cake was prepared by the screwpress process.

The actual rations fed per animal per day are given in Table 2. In addition, each animal received 30 grams iodized salt per day during the collection period.

TABLE 2.—FEEDING SCHEDULE

| Period | Feed | Kilograms of feed per animal per day given to the following animals: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H |
| 1 | Hay | 5 | – | 7 | 5 | – | – | 5 | – |
| | Barley | – | – | – | 3 | 4 | – | – | – |
| | Oats | – | – | – | – | – | – | 3 | – |
| | Oil cake | 3 | 4 | – | – | – | – | – | – |
| 2 | Hay | 7 | 5 | – | – | 5 | 5 | – | – |
| | Barley | – | – | 4 | – | 3 | – | – | – |
| | Oats | – | 3 | – | 4 | – | – | – | – |
| | Oil cake | – | – | – | – | – | 3 | 3.67 | – |
| 3 | Hay | – | 5 | – | 5 | 7 | – | 5 | – |
| | Barley | – | – | – | – | – | – | 3 | – |
| | Oats | – | – | – | 3 | – | – | – | – |
| | Oil cake | 4 | 3 | – | – | – | – | – | – |
| 4 | Hay | – | – | 5 | – | 5 | 5 | 7 | – |
| | Barley | 3 | – | – | – | – | 3 | – | – |
| | Oats | – | – | 3 | – | – | – | – | – |
| | Oil cake | – | – | – | 3 | 3 | – | – | – |
| 5 | Hay | – | 5 | 5 | 7 | – | 5 | – | – |
| | Barley | – | 3 | – | – | – | – | – | – |
| | Oats | 3 | – | – | – | – | 3 | – | – |
| | Oil cake | – | – | 3 | – | 3 | – | – | – |
| 6 | Hay | 4.92 | – | – | 4.92 | 4.92 | 7 | – | – |
| | Barley | 3 | 3 | – | – | – | – | – | – |
| | Oats | – | – | – | – | 3 | – | – | – |
| | Oil cake | – | – | 3 | 3 | – | – | – | – |
| 7 | Hay | 5 | 7 | 5 | – | – | – | 5 | – |
| | Barley | – | – | 3 | 3 | – | – | – | – |
| | Oats | 3 | – | – | – | 3 | – | – | – |
| | Oil cake | – | – | – | – | – | 3 | 3 | – |
| 8 | Oats | 3 | 3 | 3 | 3 | 3 | – | – | – |
| | Barley | – | – | – | – | – | – | 3 | – |
| 9 | Hay | – | 7 | – | – | – | – | 5 | – |
| | Barley | – | – | – | – | – | 3 | – | – |
| | Oats | – | – | – | – | – | – | 3 | – |
| 10 | Hay | – | 5 | – | – | – | – | – | 4.5 |
| | Barley | – | 3 | – | – | – | – | 3 | – |
| | Oats | – | – | – | – | – | 3 | – | – |
| 11 | Hay | – | 5 | – | – | – | 6.5 | – | 4 |
| | Barley | – | – | – | – | – | – | – | 3 |
| | Oats | – | 3 | – | – | – | – | 3 | – |

TABLE 2.—FEEDING SCHEDULE—*Continued*

| Period | Feed | Kilograms of feed per animal per day given to the following animals: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H |
| 12 | Hay | – | – | – | – | – | 5 | 7 | 5 |
| | Barley | – | 3 | – | – | – | 3 | – | – |
| | Oats | – | – | – | – | – | – | – | 3 |
| 13 | Hay | – | – | – | – | – | 5 | 5 | – |
| | Barley | – | – | – | – | – | – | 3 | 3 |
| | Oats | – | 3 | – | – | – | 3 | – | – |
| 14 | Oats | – | – | – | – | – | – | – | 3 |

The complete experimental data are given in Tables 6 to 9 inclusive in the Appendix. Summaries of these are incorporated in the text.

## RESULTS

Since the experiment was carried out in two seasons, a comparison has first been made between these seasons on the basis of the chemical compositions and digestibilities of the feeds. The results with oil cake have been omitted since it was used only in the first year. In Table 3 the chemical compositions have been compared. The only significant difference noted was in the case of the ash of the oats. A comparison of the coefficients of digestibility of the hay and mixed rations obtained in 1938–39 with those obtained in 1939–40 is presented in Table 4. There were no significant differences between the two years.

TABLE 3.—COMPARISON OF CHEMICAL COMPOSITION OF FEEDS IN 1938–1939 WITH THAT IN 1939–1940

| Feed | Year | Designation | Composition in per cent of dry matter | | | | |
|---|---|---|---|---|---|---|---|
| | | | Ash | Protein* | Ether extract | Crude fibre | N.-free extract |
| | | | % | % | % | % | % |
| Hay | 1938–39 | Means<br>Standard errors | 7.64<br>±0.17 | 13.07<br>±0.42 | 2.15<br>±0.08 | 35.41<br>±0.81 | 41.74<br>±0.33 |
| | 1939–40 | Means<br>Standard errors | 7.48<br>±0.17 | 12.61<br>±0.32 | 2.04<br>±0.09 | 36.33<br>±0.56 | 41.54<br>±0.09 |
| Barley | 1938–39 | Means<br>Standard errors | 2.90<br>±0.07 | 12.68<br>±0.16 | 1.96<br>±0.03 | 5.58<br>±0.27 | 76.87<br>±0.26 |
| | 1939–40 | Means<br>Standard errors | 2.77<br>±0.03 | 12.93<br>±0.28 | 1.42<br>±0.25 | 6.13<br>±0.08 | 76.74<br>±0.38 |
| Oats | 1938-39 | Means<br>Standard errors | 4.04<br>±0.14 | 13.29<br>±0.38 | 3.97<br>±0.14 | 12.09<br>±0.62 | 66.60<br>±0.57 |
| | 1939–40 | Means<br>Standard errors | 3.53<br>±0.10 | 12.86<br>±0.38 | 3.74<br>±0.31 | 12.00<br>±0.41 | 67.86<br>±0.28 |

*Protein Factors:
Hay = N × 6.25
Barley = N × 5.83
Oats = N × 5.83

TABLE 4.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF HAY AND MIXED RATIONS OBTAINED IN 1938–1939 WITH THOSE OBTAINED IN 1939–1940

| Feed | Year | Designation | Coefficients of digestibility in per cent | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N.-free extract |
| | | | % | % | % | % | % | % |
| Hay...... | 1938–39 | Means | 53.0 | 54.8 | 56.7 | 39.7 | 43.0 | 64.2 |
| | | Standard errors | ± 0.40 | ±0.42 | ±1.62 | ±2.85 | ±0.85 | ±0.66 |
| | 1939–40 | Means | 53.2 | 54.7 | 55.8 | 47.1 | 43.9 | 63.6 |
| | | Standard errors | ±0.49 | ±0.54 | ±0.90 | ±2.60 | ±0.96 | ±0.79 |
| Hay + Barley | 1938–39 | Means | 63.3 | 65.0 | 61.6 | 53.3 | 39.2 | 77.1 |
| | | Standard errors | ±0.76 | ±0.78 | ±1.59 | ±2.40 | ±1.12 | ±0.65 |
| | 1939–40 | Means | 63.2 | 65.1 | 61.5 | 54.6 | 43.5 | 75.2 |
| | | Standard errors | ±0.61 | ±0.63 | ±1.38 | ±0.65 | ±2.41 | ±0.80 |
| Hay + Oats | 1938–39 | Means | 58.6 | 60.2 | 64.8 | 64.0 | 38.5 | 69.8 |
| | | Standard errors | ±0.61 | ±0.63 | ±0.75 | ±1.42 | ±2.01 | ±0.34 |
| | 1939–40 | Means | 58.0 | 59.5 | 61.8 | 65.9 | 41.2 | 69.3 |
| | | Standard errors | ±1.08 | ±1.04 | ±1.32 | ±0.88 | ±3.79 | ±0.90 |

In Table 5 a summary has been made of the coefficients of digestibility and of the total digestible nutrients of the grains when fed alone and also when fed with hay. In calculating the digestibilities of the grains from the mixed rations with hay, the average digestibility of the hay for the year concerned was applied to the chemical composition for the period concerned. From this table it is evident that for oil cake there were no statistically significant differences between the observed[1] and the calculated[2] values. With the exception of the ether extract, the same was true of barley. Since, for this feed, there were no significant differences in the digestibilities of the other nutrients, nor in the total digestible nutrients, we may conclude that the barley had the same value, whether it was fed alone or with hay. With oats, on the other hand, the calculated values for the digestibilities of dry matter, organic matter and total carbohydrates, as well as the calculated values for the total digestible nutrients, were definitely less than the values obtained when the oats were fed alone. In the case of nitrogen and ether extract, however, the differences were not statistically significant. Using the total digestible nutrients of the dry matter of oats as a criterion of the feeding value, it may be said that this value for oats, determined from the calculated digestibilities, was approximately 5% less than when it was determined from the observed digestibilities.

For all three feeds, with the exception of the ether extract, the calculated values tended to be lower than the observed values, though it was only in the case of oats that any significant differences were observed. The digestibilities of ether extract calculated from a mixed ration with hay were higher than the observed values in all cases. There was such a large variance, however, among individual values that it was only in the case of barley that the difference was statistically significant.

[1] Observed values—obtained by feeding grains as the sole ration.
[2] Calculated values—calculated from mixed rations with hay.

Table 5.—Summary of coefficients of digestibility of grains

| Nutrient | Feed | Observed values† | | Calculated values‡ | | Difference | $t$* values |
|---|---|---|---|---|---|---|---|
| | | No. of individual values | Mean coeff. of digest. | No. of individual values | Mean coeff. of digest. | | |
| | | | % | | % | | |
| Dry matter | Barley | 10 | 81.7 | 11 | 80.0 | 1.7 | 1.007 |
| | Oats | 12 | 72.1 | 11 | 67.2 | 4.9 | 2.761 |
| | Oil cake | 7 | 77.7 | 7 | 75.9 | 1.8 | 1.209 |
| Organic matter | Barley | 10 | 83.4 | 11 | 81.1 | 2.3 | 1.411 |
| | Oats | 12 | 73.7 | 11 | 68.4 | 5.3 | 3.084 |
| | Oil cake | 7 | 79.7 | 7 | 77.0 | 2.7 | 1.924 |
| Nitrogen | Barley | 10 | 75.1 | 11 | 69.8 | 5.3 | 1.550 |
| | Oats | 12 | 76.1 | 11 | 74.7 | 1.4 | 0.816 |
| | Oil cake | 7 | 87.7 | 7 | 86.7 | 1.0 | 1.164 |
| Ether extract | Barley | 10 | 60.0 | 11 | 77.1 | −17.1 | 2.716 |
| | Oats | 12 | 81.2 | 11 | 86.3 | −5.1 | 2.030 |
| | Oil cake | 7 | 88.9 | 7 | 92.0 | −3.1 | 1.215 |
| Total carbohydrates | Barley | 10 | 85.0 | 11 | 82.6 | 2.4 | 1.689 |
| | Oats | 12 | 72.7 | 11 | 66.3 | 6.4 | 3.066 |
| | Oil cake | 7 | 73.9 | 7 | 69.5 | 4.4 | 2.086 |
| T.D.N. in dry matter | Barley | 10 | 82.09 | 11 | 79.90 | 2.19 | 1.448 |
| | Oats | 12 | 74.54 | 11 | 69.76 | 4.78 | 2.666 |
| | Oil cake | 7 | 83.42 | 7 | 81.31 | 2.11 | 1.507 |

*Necessary $t$ values at P of 0.05.
For 14 values—2.179
For 21 values—2.093
For 23 values—2.080

†Observed values—obtained by feeding grains as the sole ration.
‡Calculated values—calculated from mixed rations with hay.

## SUMMARY AND CONCLUSIONS

Using 8 grade Shorthorn steers, determinations were made of the coefficients of digestibility and of the total digestible nutrients in barley, oats, and oil cake when these feeds were consumed as the sole ration and when they were fed in a mixed ration with hay.

In the case of oil cake, there were no statistically significant differences between the values obtained by calculation from the mixed ration and those obtained when oil cake constituted the sole ration.

In the case of barley, with the exception of ether extract, there were likewise no statistically significant differences. The digestibility of the ether extract calculated from the mixed ration with hay was higher than that determined by feeding the barley alone.

In the case of oats, with the exception of the nitrogen and ether extract, the values calculated from the mixed ration with hay were significantly less than the values obtained when the oats were fed alone. The drop in feeding value was to the order of 5%. For the nitrogen and ether extract, there were no significant differences between the calculated and the observed values.

For all three feeds, with the exception of the ether extract, the values calculated from mixed rations with hay tended to be lower than the values obtained by feeding the grains alone. It was only in the case of oats that such differences were significant.


## ACKNOWLEDGMENT

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Table 6.—Chemical composition of feedingstuffs

| Feed | Year | Period | Moisture | In Dry Matter | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Ash | Protein* | Ether extract | Crude fibre | N-free extract |
| | | | % | % | % | % | % | % |
| Hay | 1938–39 | 1, 2 | 13.73 | 7.42 | 13.56 | 2.44 | 33.37 | 43.21 |
| | | 3 | 14.69 | 7.85 | 13.51 | 2.21 | 34.65 | 41.78 |
| | | 4 | 14.54 | 7.73 | 13.49 | 1.97 | 35.06 | 41.75 |
| | | 5 | 14.30 | 8.34 | 14.18 | 2.25 | 33.70 | 41.53 |
| | | 6 | 13.10 | 7.30 | 12.25 | 2.09 | 37.54 | 40.82 |
| | | 7 | 13.03 | 7.21 | 11.41 | 1.95 | 38.11 | 41.32 |
| | Means | | 13.90 | 7.64 | 13.07 | 2.15 | 35.41 | 41.74 |
| | S.E. | | ±0.30 | ±0.17 | ±0.42 | ±0.08 | ±0.81 | ±0.33 |
| | 1939-40 | 9 | 11.68 | 6.99 | 11.52 | 1.89 | 37.89 | 41.71 |
| | | 10 | 12.76 | 7.19 | 12.22 | 1.91 | 37.49 | 41.19 |
| | | 11 | 12.70 | 7.64 | 13.09 | 2.11 | 35.52 | 41.64 |
| | | 12 | 11.68 | 7.64 | 13.01 | 2.35 | 35.50 | 41.50 |
| | | 13 | 10.49 | 7.93 | 13.19 | 1.96 | 35.27 | 41.65 |
| | Means | | 11.86 | 7.48 | 12.61 | 2.04 | 36.33 | 41.54 |
| | S.E. | | ±0.42 | ±0.17 | ±0.32 | ±0.09 | ±0.56 | ±0.09 |
| | General means | | 12.97 | 7.57 | 12.86 | 2.10 | 35.83 | 41.65 |
| Barley | 1938–39 | 1 and 2 | 12.98 | 2.74 | 12.76 | 1.95 | 4.74 | 77.81 |
| | | 3 | 13.47 | 2.73 | 12.92 | 1.89 | 5.17 | 77.29 |
| | | 4 | 13.58 | 2.99 | 12.78 | 1.98 | 5.48 | 76.77 |
| | | 5 | 13.89 | 2.82 | 12.49 | 1.87 | 5.35 | 77.47 |
| | | 6 | 13.56 | 2.83 | 13.09 | 1.98 | 5.45 | 76.65 |
| | | 7 | 13.33 | 3.00 | 12.91 | 2.05 | 5.80 | 76.24 |
| | | 8 | 14.16 | 3.21 | 11.82 | 2.03 | 7.05 | 75.89 |
| | Means | | 13.57 | 2.90 | 12.68 | 1.96 | 5.58 | 76.87 |
| | S.E. | | ±0.14 | ±0.07 | ±0.16 | ±0.03 | ±0.27 | ±0.26 |
| | 1939–40 | 9 | 15.43 | 2.69 | 12.45 | 1.02 | 6.05 | 77.79 |
| | | 10 | 15.17 | 2.75 | 13.09 | 1.15 | 6.32 | 76.69 |
| | | 11 | 15.48 | 2.83 | 13.36 | 2.02 | 6.33 | 75.46 |
| | | 12 | 15.91 | 2.86 | 13.62 | 0.91 | 5.94 | 76.67 |
| | | 13 | 14.63 | 2.74 | 12.13 | 2.02 | 6.03 | 77.08 |
| | Means | | 15.32 | 2.77 | 12.93 | 1.42 | 6.13 | 76.74 |
| | S.E. | | ±0.21 | ±0.03 | ±0.28 | ±0.25 | ±0.08 | ±0.38 |
| | General means | | 14.30 | 2.85 | 12.79 | 1.74 | 5.81 | 76.82 |

TABLE 6.—CHEMICAL COMPOSITION OF FEEDINGSTUFFS—*Continued*

| Feed | Year | Period | Moisture | In Dry Matter | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Ash | Protein* | Ether extract | Crude fibre | N-free extract |
| | | | % | % | % | % | % | % |
| Oats | 1938–39 | 1 and 2 | 13.54 | 4.31 | 15.06 | 3.71 | 11.81 | 65.11 |
| | | 3 | 14.07 | 3.80 | 12.76 | 3.95 | 12.97 | 66.52 |
| | | 4 | 14.03 | 3.60 | 13.35 | 4.05 | 10.33 | 68.67 |
| | | 5 | 14.27 | 3.85 | 14.15 | 4.48 | 10.44 | 67.08 |
| | | 6 | 13.45 | 4.74 | 12.63 | 3.36 | 15.10 | 64.17 |
| | | 7 | 13.78 | 4.02 | 12.90 | 4.25 | 11.61 | 67.22 |
| | | 8 | 12.01 | 3.98 | 12.21 | 4.02 | 12.37 | 67.42 |
| | Means | | 13.59 | 4.04 | 13.29 | 3.97 | 12.09 | 66.60 |
| | S.E. | | ±0.29 | ±0.14 | ±0.38 | ±0.14 | ±0.62 | ±0.57 |
| | 1939–40 | 9 | 14.30 | 3.70 | 13.20 | 2.30 | 11.92 | 68.88 |
| | | 10 | 14.56 | 3.55 | 13.88 | 3.96 | 10.48 | 68.13 |
| | | 11 | 14.45 | 3.67 | 11.96 | 3.66 | 12.53 | 68.18 |
| | | 12 | 13.96 | 3.54 | 13.05 | 3.98 | 12.48 | 66.95 |
| | | 13 | 13.26 | 3.69 | 11.50 | 4.16 | 13.28 | 67.37 |
| | | 14 | 12.80 | 3.03 | 13.59 | 4.40 | 11.31 | 67.67 |
| | Means | | 13.89 | 3.53 | 12.86 | 3.74 | 12.00 | 67.86 |
| | S.E. | | ±0.29 | ±0.10 | ±0.38 | ±0.31 | ±0.41 | ±0.28 |
| | General means | | 13.73 | 3.81 | 13.10 | 3.87 | 12.05 | 67.18 |
| Oil cake | 1938–39 | 1 and 2 | 10.57 | 5.84 | 34.23 | 7.39 | 7.93 | 44.61 |
| | | 3 | 8.84 | 5.66 | 35.49 | 6.77 | 7.38 | 44.70 |
| | | 4 | 9.74 | 5.56 | 36.17 | 6.88 | 7.42 | 43.97 |
| | | 5 | 9.84 | 5.63 | 36.25 | 6.43 | 7.73 | 43.96 |
| | | 6 | 9.73 | 5.65 | 36.57 | 7.17 | 7.13 | 43.48 |
| | | 7 | 9.77 | 5.63 | 36.18 | 6.85 | 7.34 | 44.00 |
| | Means | | 9.75 | 5.66 | 35.82 | 6.92 | 7.49 | 44.12 |

*Protein Factors:—
Hay = N × 6.25
Barley = N × 5.83
Oats = N × 5.83
Oil cake = N × 5.30

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY

(Collection Period of 12 days; weights in kilograms; coefficients in per cent.)

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 1 | | | | |
| *Animal A* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In oil cake | 36.000 | 32.195 | 30.315 | 2.079 | 2.379 | 2.553 | 14.362 |
| Total | 96.000 | 83.957 | 78.236 | 3.202 | 3.642 | 19.826 | 36.728 |
| In faeces | 184.434 | 31.015 | 27.625 | 0.705 | 0.850 | 12.564 | 10.098 |
| Digested | | 52.942 | 50.611 | 2.497 | 2.792 | 7.262 | 26.630 |
| Coefficient | | 63.1 | 64.7 | 78.0 | 76.7 | 36.6 | 72.5 |
| Dig. from hay | | 27.434 | 26.261 | 0.637 | 0.501 | 7.427 | 14.359 |
| Dig. from oil cake | | 25.508 | 24.350 | 1.860 | 2.291 | − 0.165 | 12.271 |
| Coef. of oil cake | | 79.2 | 80.3 | 89.5 | 96.3 | − 6.5 | 85.4 |

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Concluded*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 1—*Concluded* | | | | |
| *Animal B* | | | | | | | |
| In oil cake | 48.000 | 42.926 | 40.419 | 2.773 | 3.172 | 3.404 | 19.149 |
| In faeces | 48.851 | 10.680 | 9.087 | 0.375 | 0.462 | 2.592 | 3.806 |
| Digested | | 32.246 | 31.332 | 2.398 | 2.710 | 0.812 | 15.343 |
| Coefficient | | 75.1 | 77.5 | 86.5 | 85.4 | 23.9 | 80.1 |
| *Animal C* | | | | | | | |
| In hay | 84.000 | 72.467 | 67.090 | 1.573 | 1.768 | 24.182 | 31.313 |
| In faeces | 181.641 | 33.930 | 30.181 | 0.635 | 0.923 | 14.420 | 11.007 |
| Digested | | 38.537 | 36.909 | 0.938 | 0.845 | 9.762 | 20.306 |
| Coefficient | | 53.2 | 55.0 | 59.6 | 47.8 | 40.4 | 64.8 |
| *Animal D* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In barley | 36.000 | 31.327 | 30.469 | 0.686 | 0.611 | 1.485 | 24.376 |
| Total | 96.000 | 83.089 | 78.390 | 1.809 | 1.874 | 18.758 | 46.742 |
| In faeces | 158.216 | 29.561 | 26.747 | 0.646 | 0.724 | 12.250 | 10.018 |
| Digested | | 53.528 | 51.643 | 1.163 | 1.150 | 6.508 | 36.724 |
| Coefficient | | 64.4 | 65.9 | 64.3 | 61.4 | 34.7 | 78.6 |
| Dig. from hay | | 27.434 | 26.261 | 0.637 | 0.501 | 7.427 | 14.359 |
| Dig. from barley | | 26.094 | 25.382 | 0.526 | 0.649 | − 0.919 | 22.365 |
| Coeff. of barley | | 83.3 | 83.3 | 76.7 | 106.2 | − 61.9 | 91.8 |
| *Animal E* | | | | | | | |
| In barley | 48.000 | 41.770 | 40.626 | 0.914 | 0.815 | 1.980 | 32.501 |
| In faeces | 38.285 | 5.877 | 5.105 | 0.204 | 0.243 | 1.266 | 2.431 |
| Digested | | 35.893 | 35.521 | 0.710 | 0.572 | 0.714 | 30.070 |
| Coefficient | | 85.9 | 87.4 | 77.7 | 70.2 | 36.1 | 92.5 |
| *Animal G* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In oats | 36.000 | 31.126 | 29.784 | 0.804 | 1.155 | 3.676 | 20.266 |
| Total | 96.000 | 82.888 | 77.705 | 1.927 | 2.418 | 20.949 | 42.632 |
| In faeces | 183.334 | 35.095 | 31.561 | 0.635 | 0.912 | 13.536 | 13.213 |
| Digested | | 47.793 | 46.144 | 1.292 | 1.506 | 7.413 | 29.419 |
| Coefficient | | 57.7 | 59.4 | 67.0 | 62.3 | 35.4 | 69.0 |
| Dig. from hay | | 27.434 | 26.261 | 0.637 | 0.501 | 7.427 | 14.359 |
| Dig. from oats | | 20.359 | 19.883 | 0.655 | 1.005 | − 0.014 | 15.060 |
| Coefficient of oats | | 65.4 | 66.8 | 81.5 | 87.0 | − 0.4 | 74.3 |
| | | | PERIOD 2 | | | | |
| *Animal A* | | | | | | | |
| In hay | 84.000 | 72.467 | 67.090 | 1.573 | 1.768 | 24.182 | 31.313 |
| In faeces | 181.211 | 32.397 | 28.743 | 0.620 | 0.891 | 14.025 | 10.092 |
| Digested | | 40.070 | 38.347 | 0.953 | 0.877 | 10.157 | 21.221 |
| Coefficient | | 55.3 | 57.2 | 60.6 | 49.6 | 42.0 | 67.8 |
| *Animal B* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In oats | 36.000 | 31.126 | 29.784 | 0.804 | 1.155 | 3.676 | 20.266 |
| Total | 96.000 | 82.888 | 77.705 | 1.927 | 2.418 | 20.949 | 42.632 |
| In faeces | 169.387 | 34.564 | 31.301 | 0.633 | 0.788 | 13.826 | 13.103 |
| Digested | | 48.324 | 46.404 | 1.294 | 1.630 | 7.123 | 29.529 |
| Coefficient | | 58.3 | 59.7 | 67.2 | 67.4 | 34.0 | 69.3 |
| Dig. from hay | | 27.434 | 26.621 | 0.637 | 0.501 | 7.427 | 14.359 |
| Dig. from oats | | 20.890 | 20.143 | 0.657 | 1.129 | − 0.304 | 15.170 |
| Coefficient of oats | | 67.1 | 67.6 | 81.7 | 97.7 | − 8.3 | 74.9 |

Table 7.—Calculation of coefficients of digestibility—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | Period 2—*Concluded* | | | | |
| *Animal C** | | | | | | | |
| In barley | 16.000 | 13.923 | 13.542 | 0.305 | 0.271 | 0.660 | 10.833 |
| In faeces | 11.871 | 2.232 | 1.991 | 0.059 | 0.086 | 0.753 | 0.791 |
| Digested | | 11.691 | 11.551 | 0.246 | 0 185 | − 0.093 | 10.042 |
| Coefficient | | 84.0 | 85.3 | 80.7 | 68.3 | − 14.1 | 92.7 |
| *Animal D* | | | | | | | |
| In oats | 48.000 | 41.501 | 39.712 | 1.072 | 1.540 | 4.901 | 27.021 |
| In faeces | 54.876 | 14 210 | 12.556 | 0.238 | 0.502 | 3.861 | 6.713 |
| Digested | | 27.291 | 27.156 | 0 834 | 1.038 | 1.040 | 20.308 |
| Coefficient | | 65.8 | 68.4 | 77.8 | 67.4 | 21.2 | 75.2 |
| *Animal E* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In barley | 36.000 | 31.327 | 30.469 | 0.686 | 0.611 | 1.485 | 24.376 |
| Total | 96.000 | 83 089 | 78.390 | 1.809 | 1.874 | 18.758 | 46.742 |
| In faeces | 158.637 | 27.722 | 24.828 | 0.575 | 0.715 | 11.117 | 9 647 |
| Digested | | 55.367 | 53.562 | 1.234 | 1.159 | 7.641 | 37.095 |
| Coefficient | | 66.6 | 68.3 | 68.2 | 61.8 | 40.7 | 79.4 |
| Dig. from hay | | 27.434 | 26 261 | 0.637 | 0.501 | 7.427 | 14.359 |
| Dig. from barley | | 27.933 | 27.301 | 0.597 | 0.658 | 0.214 | 22.736 |
| Coefficient of barley | | 89.2 | 89.6 | 87.0 | 107.7 | 14.4 | 93.3 |
| *Animal F* | | | | | | | |
| In hay | 60.000 | 51.762 | 47.921 | 1.123 | 1.263 | 17.273 | 22.366 |
| In oil cake | 36.000 | 32.195 | 30.315 | 2.079 | 2.379 | 2.553 | 14.362 |
| Total | 96.000 | 83.957 | 78 236 | 3.202 | 3.642 | 19.826 | 36.728 |
| In faeces | 193.392 | 32.052 | 28.722 | 0.755 | 0.885 | 12.798 | 10.494 |
| Digested | | 51.905 | 49.514 | 2.447 | 2.757 | 7.028 | 26.234 |
| Coefficient | | 61.8 | 63.3 | 76 4 | 75.7 | 35.4 | 71.4 |
| Dig. from hay | | 27 434 | 26.261 | 0 637 | 0.501 | 7.427 | 14.359 |
| Dig. from oil cake | | 24.471 | 23.253 | 1 810 | 2.256 | − 0.399 | 11.875 |
| Coeff. of oil cake | | 76 0 | 76.7 | 87.1 | 94.8 | − 15.6 | 82.7 |
| *Animal G* | | | | | | | |
| In oil cake | 44.000 | 39.319 | 37 051 | 2.542 | 2.908 | 3.120 | 17.554 |
| In faeces | 52.382 | 10.250 | 8 563 | 0 391 | 0.536 | 2.424 | 3.433 |
| Digested | | 29.099 | 28.488 | 2.151 | 2.372 | 0.696 | 14.121 |
| Coefficient | | 74.0 | 76.9 | 84.6 | 81.6 | 22.3 | 80.4 |
| | | | Period 3 | | | | |
| *Animal A* | | | | | | | |
| In oil cake | 48.000 | 43.757 | 41.280 | 2.930 | 2.962 | 3.229 | 19.559 |
| In faeces | 54.593 | 9.325 | 8.170 | 0.346 | 0.331 | 2.385 | 3.385 |
| Digested | | 34.432 | 33.110 | 2.584 | 2.631 | 0.844 | 16.174 |
| Coefficient | | 78.7 | 80.2 | 88.2 | 88.8 | 26.1 | 82.7 |
| *Animal B* | | | | | | | |
| In hay | 60.000 | 51.186 | 47.168 | 1.107 | 1.131 | 17.736 | 21.386 |
| In oil cake | 36.000 | 32.818 | 30 961 | 2.197 | 2.222 | 2.422 | 14.670 |
| Total | 96.000 | 84.004 | 78 129 | 3.304 | 3.353 | 20.158 | 36.056 |
| In faeces | 178.247 | 33.110 | 29 643 | 0.756 | 0.821 | 13.102 | 11.257 |
| Digested | | 50.894 | 48 486 | 2.548 | 2.532 | 7.056 | 24.799 |
| Coefficient | | 60.6 | 62 1 | 77.1 | 75.5 | 35.0 | 68.8 |
| Dig. from hay | | 27.129 | 25 848 | 0.628 | 0.449 | 7.626 | 13.730 |
| Dig. from oil cake | | 23.765 | 22 638 | 1.920 | 2.083 | − 0.570 | 11.069 |
| Coeff. of oil cake | | 72.4 | 73.1 | 87.4 | 93.7 | − 23.5 | 75.5 |

*Collection period of 4 days.

TABLE 7.—CALCULATIONS OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| PERIOD 3—*Concluded* | | | | | | | |
| *Animal D* | | | | | | | |
| In hay | 60.000 | 51.186 | 47.168 | 1.107 | 1.131 | 17.736 | 21.386 |
| In oats | 36.000 | 30.935 | 29.759 | 0.677 | 1.222 | 4.012 | 20.578 |
| Total | 96.000 | 82.121 | 76.927 | 1.784 | 2.353 | 21.748 | 41.964 |
| In faeces | 163.293 | 33.853 | 30.617 | 0.634 | 0.782 | 13.328 | 12.691 |
| Digested | | 48.268 | 46.310 | 1.150 | 1.571 | 8.420 | 29.273 |
| Coefficient | | 58.8 | 60.2 | 64.5 | 66.8 | 38.7 | 69.8 |
| Dig. from hay | | 27.129 | 25.848 | 0.628 | 0.449 | 7.626 | 13.730 |
| Dig. from oats | | 21.139 | 20.462 | 0.522 | 1.122 | 0.794 | 15.543 |
| Coeff. of oats | | 68.3 | 68.8 | 77.1 | 91.8 | 19.8 | 75.5 |
| *Animal E* | | | | | | | |
| In hay | 84.000 | 71.660 | 66.035 | 1.550 | 1.584 | 24.830 | 29.940 |
| In faeces | 191.443 | 33.745 | 30.168 | 0.608 | 0.908 | 14.676 | 10.849 |
| Digested | | 37.915 | 35.867 | 0.942 | 0.676 | 10.154 | 19.091 |
| Coefficient | | 52.9 | 54.3 | 60.8 | 42.7 | 40.9 | 63.8 |
| *Animal G* | | | | | | | |
| In hay | 60.000 | 51.186 | 47.168 | 1.107 | 1.131 | 17.736 | 21.386 |
| In barley | 36.000 | 31.151 | 30.301 | 0.691 | 0.589 | 1.611 | 24.077 |
| Total | 96.000 | 82.337 | 77.469 | 1.798 | 1.720 | 19.347 | 45.463 |
| In faeces | 179.706 | 30.909 | 27.694 | 0.680 | 0.906 | 12.203 | 10.521 |
| Digested | | 51.428 | 49.775 | 1.118 | 0.814 | 7.144 | 34.942 |
| Coefficient | | 62.5 | 64.3 | 62.2 | 47.3 | 36.9 | 76.9 |
| Dig. from hay | | 27.129 | 25.848 | 0.628 | 0.449 | 7.626 | 13.730 |
| Dig. from barley | | 24.299 | 23.927 | 0.490 | 0.365 | − 0.482 | 21.212 |
| Coeff. of barley | | 78.0 | 79.0 | 70.9 | 62.0 | − 29.9 | 88.1 |
| PERIOD 4 | | | | | | | |
| *Animal A*†* | | | | | | | |
| In barley | 18.000 | 15.556 | 15.091 | 0.341 | 0.308 | 0.852 | 11.942 |
| In faeces | 15.480 | 2.951 | 2.602 | 0.078 | 0.096 | 0.859 | 1.193 |
| Digested | | 12.605 | 12.489 | 0.263 | 0.212 | − 0.007 | 10.749 |
| Coefficient | | 81.0 | 82.8 | 77.1 | 68.8 | − 0.8 | 90.0 |
| *Animal C* | | | | | | | |
| In hay | 60.000 | 51.276 | 47.312 | 1.107 | 1.010 | 17.977 | 21.408 |
| In oats | 36.000 | 30.949 | 29.835 | 0.709 | 1.253 | 3.197 | 21.253 |
| Total | 96.000 | 82.225 | 77.147 | 1.816 | 2.263 | 21.174 | 42.661 |
| In faeces | 215.299 | 36.112 | 32.479 | 0.697 | 0.917 | 14.095 | 13.174 |
| Digested | | 46.113 | 44.668 | 1.119 | 1.346 | 7.079 | 29.487 |
| Coefficient | | 56.1 | 57.9 | 61.6 | 59.5 | 33.4 | 69.1 |
| Digested from hay | | 27.176 | 25.927 | 0.628 | 0.401 | 7.730 | 13.744 |
| Dig. from oats | | 18.937 | 18.741 | 0.491 | 0.945 | − 0.651 | 15.743 |
| Coeff. of oats | | 61.2 | 62.8 | 69.3 | 75.4 | − 20.4 | 74.1 |
| *Animal D* | | | | | | | |
| In oil cake | 36.000 | 32.494 | 30.687 | 2.218 | 2.236 | 2.411 | 14.288 |
| In faeces | 29.710 | 6.997 | 5.899 | 0.254 | 0.227 | 1.672 | 2.459 |
| Digested | | 25.497 | 24.788 | 1.964 | 2.009 | 0.739 | 11.829 |
| Coefficient | | 78.5 | 80.8 | 88.5 | 89.8 | 30.7 | 82.8 |
| *Animal E* | | | | | | | |
| In hay | 60.000 | 51.276 | 47.312 | 1.107 | 1.010 | 17.977 | 21.408 |
| In oil cake | 36.000 | 32.494 | 30.687 | 2.218 | 2.236 | 2.411 | 14.288 |
| Total | 96.000 | 83.770 | 77.999 | 3.325 | 3.246 | 20.388 | 35.696 |
| In faeces | 211.926 | 30.687 | 27.152 | 0.759 | 0.893 | 11.557 | 10.262 |
| Digested | | 53.083 | 50.847 | 2.566 | 2.353 | 8.831 | 25.434 |
| Coefficient | | 63.4 | 65.2 | 77.2 | 72.5 | 43.3 | 71.3 |
| Dig. from hay | | 27.176 | 25.927 | 0.628 | 0.401 | 7.730 | 13.744 |
| Dig. from oil cake | | 25.907 | 24.920 | 1.938 | 1.952 | 1.101 | 11.690 |
| Coeff. of oil cake | | 79.7 | 81.2 | 87.4 | 87.3 | 45.7 | 81.8 |

*†Collection period of 10 days.

Table 7.—Calculation of coefficients of digestibility—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | Period 4—*Concluded* | | | | |
| *Animal F* | | | | | | | |
| In hay | 60.000 | 51.276 | 47.312 | 1.107 | 1.010 | 17.977 | 21.408 |
| In barley | 36.000 | 31.111 | 30.181 | 0.682 | 0.616 | 1.705 | 23.884 |
| Total | 96.000 | 82.387 | 77.493 | 1.789 | 1.626 | 19.682 | 45.292 |
| In faeces | 173.393 | 30.475 | 27.296 | 0.677 | 0.878 | 11.547 | 10.843 |
| Digested | | 51.912 | 50.197 | 1.112 | 0.748 | 8.135 | 34.449 |
| Coefficient | | 63.0 | 64.8 | 62.2 | 46.0 | 41.3 | 76.1 |
| Dig. from hay | | 27.176 | 25.927 | 0.628 | 0.401 | 7.730 | 13.744 |
| Dig. from barley | | 24.736 | 24.270 | 0.484 | 0.347 | 0.405 | 20.705 |
| Coff. of barley | | 79.5 | 80.4 | 71.0 | 56.3 | 23.8 | 86.7 |
| *Animal G* | | | | | | | |
| In hay | 84.000 | 71.786 | 66.237 | 1.549 | 1.414 | 25.168 | 29.971 |
| In faeces | 172.739 | 34.052 | 30.194 | 0.649 | 0.994 | 14.506 | 10.706 |
| Digested | | 37.734 | 36.043 | 0.900 | 0.420 | 10.662 | 19.265 |
| Coefficient | | 52.6 | 54.4 | 58.1 | 29.7 | 42.4 | 64.3 |
| | | | Period 5 | | | | |
| *Animal A*† | | | | | | | |
| In oats | 24.000 | 20.575 | 19.783 | 0.500 | 0.922 | 2.148 | 13.802 |
| In faeces | 29.171 | 5.246 | 4.823 | 0.103 | 0.134 | 1.656 | 2.508 |
| Digested | | 15.329 | 14.960 | 0.397 | 0.788 | 0.492 | 11.294 |
| Coefficient | | 74.5 | 75.6 | 79.4 | 85.5 | 22.9 | 81.8 |
| *Animal B* | | | | | | | |
| In hay | 60.000 | 51.420 | 47.132 | 1.167 | 1.157 | 17.329 | 21.355 |
| In barley | 36.000 | 31.000 | 30.126 | 0.664 | 0.580 | 1.659 | 24.016 |
| Total | 96.000 | 82.420 | 77.258 | 1.831 | 1.737 | 18.988 | 45.371 |
| In faeces | 159.906 | 31.068 | 27.570 | 0.731 | 0.876 | 11.660 | 10.659 |
| Digested | | 51.352 | 49.688 | 1.100 | 0.861 | 7.328 | 34.712 |
| Coefficient | | 62.3 | 64.3 | 60.1 | 49.6 | 38.6 | 76.5 |
| Dig. from hay | | 27.253 | 25.828 | 0.662 | 0.459 | 7.451 | 13.710 |
| Dig. from barley | | 24.099 | 23.860 | 0.438 | 0.402 | − 0.123 | 21.002 |
| Coeff. of barley | | 77.7 | 79.2 | 66.0 | 69.3 | − 7.4 | 87.5 |
| *Animal C* | | | | | | | |
| In hay | 60.000 | 51.420 | 47.132 | 1.167 | 1.157 | 17.329 | 21.355 |
| In oil cake | 36.000 | 32.458 | 30.631 | 2.220 | 2.087 | 2.509 | 14.269 |
| Total | 96.000 | 83.878 | 77.763 | 3.387 | 3.244 | 19.838 | 35.624 |
| In faeces | 211.068 | 33.548 | 29.693 | 0.836 | 1.060 | 11.963 | 11.581 |
| Digested | | 50.330 | 48.070 | 2.551 | 2.184 | 7.875 | 24.043 |
| Coefficient | | 60.0 | 61.8 | 75.3 | 67.3 | 39.7 | 67.5 |
| Dig. from hay | | 27.253 | 25.828 | 0.662 | 0.459 | 7.451 | 13.710 |
| Dig. from oil cake | | 23.077 | 22.242 | 1.889 | 1.725 | 0.424 | 10.333 |
| Coeff. of oil cake | | 71.1 | 72.6 | 85.1 | 82.7 | 16.9 | 72.4 |
| *Animal D* | | | | | | | |
| In hay | 84.000 | 71.988 | 65.984 | 1.633 | 1.620 | 24.260 | 29.897 |
| In faeces | 183.753 | 34.167 | 30.009 | 0.715 | 1.069 | 13.455 | 11.101 |
| Digested | | 37.821 | 35.975 | 0.918 | 0.551 | 10.805 | 18.796 |
| Coefficient | | 52.5 | 54.5 | 56.2 | 34.0 | 44.5 | 62.9 |
| *Animal E* | | | | | | | |
| In oil cake | 36.000 | 32.458 | 30.631 | 2.220 | 2.087 | 2.509 | 14.269 |
| In faeces | 35.705 | 6.674 | 5.777 | 0.250 | 0.167 | 1.582 | 2.538 |
| Digested | | 25.784 | 24.854 | 1.970 | 1.920 | 0.927 | 11.731 |
| Coefficient | | 79.4 | 81.1 | 88.7 | 92.0 | 36.9 | 82.2 |

†Collection period of 8 days.

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 5—*Concluded* | | | | |
| *Animal F* | | | | | | | |
| In hay | 60.000 | 51.420 | 47.132 | 1.167 | 1.157 | 17.329 | 21.355 |
| In oats | 36.000 | 30.863 | 29.675 | 0.749 | 1.383 | 3.222 | 20.703 |
| Total | 96.000 | 82.283 | 76.807 | 1.916 | 2.540 | 20.551 | 42.058 |
| In faeces | 215.716 | 34.406 | 30.790 | 0.697 | 0.912 | 12.806 | 12.988 |
| Digested | | 47.877 | 46.017 | 1.219 | 1.628 | 7.745 | 29.070 |
| Coefficient | | 58.2 | 59.9 | 63.6 | 64.1 | 37.7 | 69.1 |
| Dig. from hay | | 27.253 | 25.828 | 0.662 | 0.459 | 7.451 | 13.710 |
| Dig. from oats | | 20.624 | 20.189 | 0.557 | 1.169 | 0.294 | 15.360 |
| Coeff. of oats | | 66.8 | 68.0 | 74.4 | 84.5 | 9.1 | 74.2 |
| | | | PERIOD 6 | | | | |
| *Animal A* | | | | | | | |
| In hay | 59.000 | 51.271 | 47.528 | 1.005 | 1.072 | 19.247 | 20.929 |
| In barley | 36.000 | 31.118 | 30.237 | 0.699 | 0.616 | 1.696 | 23.852 |
| Total | 95.000 | 82.389 | 77.765 | 1.704 | 1.688 | 20.943 | 44.781 |
| In faeces | 198.170 | 29.709 | 26.545 | 0.691 | 0.799 | 11.818 | 9.881 |
| Digested | | 52.680 | 51.220 | 1.013 | 0.889 | 9.125 | 34.900 |
| Coefficient | | 63.9 | 65.9 | 59.4 | 52.7 | 43.6 | 77.9 |
| Dig. from hay | | 27.174 | 26.045 | 0.570 | 0.426 | 8.276 | 13.436 |
| Dig. from barley | | 25.506 | 25.175 | 0.443 | 0.463 | 0.849 | 21.464 |
| Coeff. of barley | | 82.0 | 83.3 | 63.4 | 75.2 | 50.1 | 90.0 |
| *Animal B* | | | | | | | |
| In barley | 36.000 | 31.118 | 30.237 | 0.699 | 0.616 | 1.696 | 23.852 |
| In faeces | 26.054 | 5.990 | 5.449 | 0.186 | 0.274 | 1.748 | 2.318 |
| Digested | | 25.128 | 24.788 | 0.513 | 0.342 | − 0.052 | 21.534 |
| Coefficient | | 80.8 | 82.0 | 73.4 | 55.5 | − 3.1 | 90.3 |
| *Animal C* | | | | | | | |
| In oil cake | 36.000 | 32.497 | 30.661 | 2.242 | 2.330 | 2.317 | 14.130 |
| In faeces | 35.253 | 6.902 | 5.989 | 0.257 | 0.180 | 1.805 | 2.491 |
| Digested | | 25.595 | 24.672 | 1.985 | 2.150 | 0.512 | 11.639 |
| Coefficient | | 78.8 | 80.5 | 88.5 | 92.3 | 22.1 | 82.4 |
| *Animal D* | | | | | | | |
| In hay | 59.000 | 51.271 | 47.528 | 1.000 | 1.072 | 19.247 | 20.929 |
| In oil cake | 36.000 | 32.497 | 30.661 | 2.242 | 2.330 | 2.317 | 14.130 |
| Total | 95.000 | 83.768 | 78.189 | 3.247 | 3.402 | 21.564 | 35.059 |
| In faeces | 190.175 | 32.103 | 28.633 | 0.765 | 0.851 | 12.048 | 11.079 |
| Digested | | 51.665 | 49.556 | 2.482 | 2.551 | 9.516 | 23.980 |
| Coefficient | | 61.7 | 63.4 | 76.4 | 75.0 | 44.1 | 68.4 |
| Dig. from hay | | 27.174 | 26.045 | 0.570 | 0.426 | 8.276 | 13.436 |
| Dig. from oil cake | | 24.491 | 23.511 | 1.912 | 2.125 | 1.240 | 10.544 |
| Coeff. of oil cake | | 75.4 | 76.7 | 85.3 | 91.2 | 53.5 | 74.6 |
| *Animal E* | | | | | | | |
| In hay | 59.000 | 51.271 | 47.528 | 1.005 | 1.072 | 19.247 | 20.929 |
| In oats | 36.000 | 31.158 | 29.681 | 0.675 | 1.047 | 4.705 | 19.994 |
| Total | 95.000 | 82.429 | 77.209 | 1.680 | 2.119 | 23.952 | 40.923 |
| In faeces | 180.953 | 31.963 | 28.428 | 0.579 | 0.860 | 12.277 | 11.727 |
| Digested | | 50.466 | 48.781 | 1.101 | 1.259 | 11.675 | 29.196 |
| Coefficient | | 61.2 | 63.2 | 65.5 | 49.4 | 48.7 | 71.3 |
| Dig. from hay | | 27.174 | 26.045 | 0.570 | 0.426 | 8.276 | 13.436 |
| Dig. from oats | | 23.292 | 22.736 | 0.531 | 0.833 | 3.399 | 15.760 |
| Coeff. of oats | | 74.8 | 76.6 | 78.7 | 79.6 | 72.2 | 78.8 |
| *Animal F* | | | | | | | |
| In hay | 84.000 | 72.996 | 67.667 | 1.431 | 1.526 | 27.403 | 29.797 |
| In faeces | 205.618 | 34.706 | 30.881 | 0.711 | 1.010 | 14.583 | 11.130 |
| Digested | | 38.290 | 36.786 | 0.720 | 0.516 | 12.820 | 18.667 |
| Coefficient | | 52.5 | 54.4 | 50.3 | 33.8 | 46.8 | 62.6 |

Table 7.—Calculation of coefficients of digestibility—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | | Period 7 | | | |
| *Animal A* | | | | | | | |
| In hay | 60.000 | 52.182 | 48.420 | 0.952 | 1.018 | 19.887 | 21.562 |
| In oats | 36.000 | 31.039 | 29.791 | 0.687 | 1.319 | 3.604 | 20.864 |
| Total | 96.000 | 83.221 | 78.211 | 1.639 | 2.337 | 23.491 | 42.426 |
| In faeces | 214.235 | 33.373 | 30.283 | 0.589 | 0.734 | 13.765 | 12.448 |
| Digested | | 49.848 | 47.928 | 1.050 | 1.603 | 9.735 | 29.978 |
| Coefficient | | 59.9 | 61.3 | 64.1 | 68.6 | 41.4 | 70.7 |
| Dig. from hay | | 27.656 | 26.534 | 0.540 | 0.404 | 8.551 | 13.843 |
| Dig. from oats | | 22.192 | 21.394 | 0.510 | 1.199 | 1.184 | 16.135 |
| Coeff. of oats | | 71.5 | 71.8 | 74.2 | 90.9 | 32.9 | 77.3 |
| *Animal B* | | | | | | | |
| In hay | 84.000 | 73.055 | 67.788 | 1.333 | 1.425 | 27.841 | 30.186 |
| In faeces | 174.526 | 34.965 | 31.350 | 0.645 | 0.850 | 15.566 | 11.045 |
| Digested | | 38.090 | 36.438 | 0.688 | 0.575 | 12.275 | 19.141 |
| Coefficient | | 52.1 | 53.8 | 51.6 | 40.4 | 44.1 | 63.4 |
| *Animal C* | | | | | | | |
| In hay | 60.000 | 52.182 | 48.420 | 0.952 | 1.018 | 19.887 | 21.562 |
| In barley | 36.000 | 31.201 | 30.265 | 0.690 | 0.640 | 1.810 | 23.788 |
| Total | 96.000 | 83.383 | 78.685 | 1.642 | 1.658 | 21.697 | 45.350 |
| In faeces | 214.888 | 33.272 | 30.258 | 0.744 | 0.759 | 13.352 | 11.718 |
| Digested | | 50.111 | 48.427 | 0.898 | 0.899 | 8.345 | 33.632 |
| Coefficient | | 60.1 | 61.5 | 54.7 | 54.2 | 38.5 | 74.2 |
| Dig. from hay | | 27.656 | 26.534 | 0.540 | 0.404 | 8.551 | 13.843 |
| Dig. from barley | | 22.455 | 21.893 | 0.358 | 0.495 | − 0.206 | 19.789 |
| Coeff. of barley | | 72.0 | 72.3 | 51.9 | 77.3 | − 11.4 | 83.2 |
| *Animal D* | | | | | | | |
| In barley | 36.000 | 31.201 | 30.265 | 0.690 | 0.640 | 1.810 | 23.788 |
| In faeces | 25.853 | 5.340 | 4.799 | 0.213 | 0.320 | 1.006 | 2.208 |
| Digested | | 25.861 | 25.466 | 0.477 | 0.320 | 0.804 | 21.580 |
| Coefficient | | 82.9 | 84.1 | 69.1 | 50.0 | 44.4 | 90.7 |
| *Animal E* | | | | | | | |
| In oats | 36.000 | 31.039 | 29.791 | 0.687 | 1.319 | 3.604 | 20.864 |
| In faeces | 35.718 | 8.069 | 7.311 | 0.165 | 0.179 | 2.355 | 3.830 |
| Digested | | 22.970 | 22.480 | 0.522 | 1.140 | 1.249 | 17.034 |
| Coefficient | | 74.0 | 75.5 | 76.0 | 86.4 | 34.7 | 81.6 |
| *Animal F* | | | | | | | |
| In oil cake | 36.000 | 32.483 | 30.654 | 2.218 | 2.225 | 2.384 | 14.293 |
| In faeces | 33.877 | 6.600 | 5.881 | 0.242 | 0.165 | 1.661 | 2.569 |
| Digested | | 25.883 | 24.773 | 1.976 | 2.060 | 0.723 | 11.724 |
| Coefficient | | 79.7 | 80.8 | 89.1 | 92.6 | 30.3 | 82.0 |
| *Animal G* | | | | | | | |
| In hay | 60.000 | 52.182 | 48.420 | 0.952 | 1.018 | 19.887 | 21.562 |
| In oil cake | 36.000 | 32.483 | 30.654 | 2.218 | 2.225 | 2.384 | 14.293 |
| Total | 96.000 | 84.665 | 79.074 | 3.170 | 3.243 | 22.271 | 35.855 |
| In faeces | 174.511 | 31.910 | 28.582 | 0.737 | 0.664 | 12.786 | 10.715 |
| Digested | | 52.755 | 50.492 | 2.433 | 2.579 | 9.485 | 25.140 |
| Coefficient | | 62.3 | 63.9 | 76.8 | 79.5 | 42.6 | 70.1 |
| Dig. from hay | | 27.656 | 26.534 | 0.540 | 0.404 | 8.551 | 13.843 |
| Dig. from oil cake | | 25.099 | 23.958 | 1.893 | 2.175 | 0.934 | 11.297 |
| Coeff. of oil cake | | 77.3 | 78.2 | 85.3 | 97.8 | 39.2 | 79.0 |

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 8 | | | | |
| *Animal A* | | | | | | | |
| In oats | 36.000 | 31.676 | 30.415 | 0.663 | 1.273 | 3.918 | 21.356 |
| In faeces | 49.887 | 6.625 | 5.881 | 0.170 | 0.233 | 1.768 | 2.923 |
| Digested | | 25.051 | 24.534 | 0.493 | 1.040 | 2.150 | 18.433 |
| Coefficient | | 79.1 | 80.7 | 74.4 | 81.7 | 54.9 | 86.3 |
| *Animal B* | | | | | | | |
| In oats | 24.000 | 21.118 | 20.278 | 0.442 | 0.849 | 2.612 | 14.238 |
| In faeces | 20.627 | 5.117 | 4.533 | 0.099 | 0.126 | 1.701 | 2.200 |
| Digested | | 16.001 | 15.745 | 0.343 | 0.723 | 0.911 | 12.038 |
| Coefficient | | 75.8 | 77.6 | 77.6 | 85.2 | 34.9 | 84.5 |
| *Animal C* | | | | | | | |
| In oats | 36.000 | 31.676 | 30.415 | 0.663 | 1.273 | 3.918 | 21.356 |
| In faeces | 36.761 | 9.479 | 8.495 | 0.178 | 0.312 | 2.763 | 4.594 |
| Digested | | 22.197 | 21.920 | 0.485 | 0.961 | 1.155 | 16.762 |
| Coefficient | | 70.1 | 72.1 | 73.2 | 75.5 | 29.5 | 78.5 |
| *Animal D* | | | | | | | |
| In oats | 36.000 | 31.676 | 30.415 | 0.663 | 1.273 | 3.918 | 21.356 |
| In faeces | 27.655 | 8.620 | 7.718 | 0.146 | 0.246 | 2.570 | 4.110 |
| Digested | | 23.056 | 22.697 | 0.517 | 1.027 | 1.348 | 17.246 |
| Coefficient | | 72.8 | 74.6 | 78.0 | 80.7 | 34.4 | 80.8 |
| *Animal E* | | | | | | | |
| In oats | 36.000 | 31.676 | 30.415 | 0.663 | 1.273 | 3.918 | 21.356 |
| In faeces | 36.260 | 8.487 | 7.641 | 0.166 | 0.229 | 2.385 | 4.162 |
| Digested | | 23.189 | 22.774 | 0.497 | 1.044 | 1.533 | 17.194 |
| Coefficient | | 73.2 | 74.9 | 75.0 | 82.0 | 39.1 | 80.5 |
| *Animal G* | | | | | | | |
| In barley | 30.000 | 25.752 | 24.925 | 0.522 | 0.523 | 1.816 | 19.543 |
| In faeces | 31.787 | 6.133 | 5.152 | 0.198 | 0.229 | 1.183 | 2.591 |
| Digested | | 19.619 | 19.773 | 0.324 | 0.294 | 0.633 | 16.952 |
| Coefficient | | 76.2 | 79.3 | 62.1 | 56.2 | 34.9 | 86.7 |
| | | | PERIOD 9 | | | | |
| *Animal B* | | | | | | | |
| In hay | 84.000 | 74.189 | 69.003 | 1.368 | 1.402 | 28.110 | 30.944 |
| In faeces | 156.686 | 33.675 | 30.277 | 0.612 | 0.737 | 15.255 | 10.638 |
| Digested | | 40.514 | 38.726 | 0.756 | 0.665 | 12.855 | 20.306 |
| Coefficient | | 54.6 | 56.1 | 55.3 | 47.4 | 45.7 | 65.6 |
| *Animal F*** | | | | | | | |
| In barley | 18.000 | 15.223 | 14.814 | 0.325 | 0.155 | 0.921 | 11.842 |
| In faeces | 13.692 | 2.397 | 2.069 | 0.078 | 0.068 | 0.770 | 0.850 |
| Digested | | 12.826 | 12.745 | 0.247 | 0.087 | 0.151 | 10.992 |
| Coefficient | | 84.3 | 86.0 | 76.0 | 56.1 | 16.4 | 92.8 |
| *Animal G* | | | | | | | |
| In hay | 60.000 | 52.992 | 49.288 | 0.977 | 1.002 | 20.079 | 22.103 |
| In oats | 36.000 | 30.852 | 29.710 | 0.699 | 0.710 | 3.678 | 21.251 |
| Total | 96.000 | 83.844 | 78.998 | 1.676 | 1.712 | 23.757 | 43.354 |
| In faeces | 164.931 | 33.056 | 30.094 | 0.580 | 0.612 | 13.632 | 12.350 |
| Digested | | 50.788 | 48.904 | 1.096 | 1.100 | 10.125 | 31.004 |
| Coefficient | | 60.6 | 61.9 | 65.4 | 64.3 | 42.6 | 71.5 |
| Dig. from hay | | 28.192 | 26.961 | 0.545 | 0.472 | 8.815 | 14.058 |
| Dig. from oats | | 22.596 | 21.943 | 0.551 | 0.628 | 1.310 | 16.946 |
| Coeff. of oats | | 73.2 | 73.9 | 78.8 | 88.5 | 35.6 | 79.7 |

**Collection period of 6 days.

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 10 | | | | |
| *Animal B* | | | | | | | |
| In hay | 60.000 | 52.344 | 48.580 | 1.024 | 1.000 | 19.624 | 21.560 |
| In barley | 36.000 | 30.539 | 29.699 | 0.685 | 0.351 | 1.930 | 23.420 |
| Total | 96.000 | 82.883 | 78.279 | 1.709 | 1.351 | 21.554 | 44.980 |
| In faeces | 150.861 | 30.274 | 26.850 | 0.642 | 0.636 | 10.711 | 12.025 |
| Digested | | 52.609 | 51.429 | 1.067 | 0.715 | 10.843 | 32.955 |
| Coefficient | | 63.5 | 65.7 | 62.4 | 52.9 | 50.3 | 73.3 |
| Dig. from hay | | 27.847 | 26.573 | 0.571 | 0.471 | 8.615 | 13.712 |
| Dig. from barley | | 24.762 | 24.856 | 0.496 | 0.244 | 2.228 | 19.243 |
| Coeff. of barley | | 81.1 | 83.7 | 72.4 | 69.5 | 115.4 | 82.2 |
| *Animal H*† | | | | | | | |
| In hay | 45.000 | 39.258 | 36.435 | 0.768 | 0.750 | 14.718 | 16.170 |
| In faeces | 105.183 | 18.697 | 16.896 | 0.357 | 0.387 | 8.604 | 5.824 |
| Digested | | 20.561 | 19.539 | 0.411 | 0.363 | 6.114 | 10.346 |
| Coefficient | | 52.4 | 53.6 | 53.5 | 48.4 | 41.5 | 64.0 |
| *Animal F* | | | | | | | |
| In oats | 36.000 | 30.758 | 29.666 | 0.732 | 1.218 | 3.223 | 20.955 |
| In faeces | 32.467 | 8.548 | 7.735 | 0.146 | 0.291 | 2.717 | 3.948 |
| Digested | | 22.210 | 21.931 | 0.586 | 0.927 | 0.506 | 17.007 |
| Coefficient | | 72.2 | 73.9 | 80.1 | 76.1 | 15.7 | 81.2 |
| *Animal G**† | | | | | | | |
| In barley | 30.000 | 25.449 | 24.749 | 0.571 | 0.293 | 1.608 | 19.517 |
| In faeces | 21.270 | 4.602 | 3.950 | 0.110 | 0.117 | 1.340 | 1.883 |
| Digested | | 20.847 | 20.799 | 0.461 | 0.176 | 0.268 | 17.634 |
| Coefficient | | 81.9 | 84.0 | 80.7 | 60.1 | 16.7 | 90.4 |
| | | | PERIOD 11 | | | | |
| *Animal B* | | | | | | | |
| In hay | 60.000 | 52.380 | 48.378 | 1.097 | 1.105 | 18.605 | 21.811 |
| In oats | 36.000 | 30.798 | 29.668 | 0.632 | 1.127 | 3.859 | 20.998 |
| Total | 96.000 | 83.178 | 78.046 | 1.729 | 2.232 | 22.464 | 42.809 |
| In faeces | 165.044 | 34.332 | 30.943 | 0.660 | 0.776 | 13.242 | 12.809 |
| Digested | | 48.846 | 47.103 | 1.069 | 1.456 | 9.222 | 30.000 |
| Coefficient | | 58.7 | 60.4 | 61.8 | 65.2 | 51.1 | 70.1 |
| Dig. from hay | | 27.866 | 26.463 | 0.612 | 0.520 | 8.168 | 13.872 |
| Dig. from oats | | 20.980 | 20.640 | 0.457 | 0.936 | 1.054 | 16.128 |
| Coeff. of oats | | 68.1 | 69.6 | 72.3 | 83.1 | 27.3 | 76.8 |
| *Animal H* | | | | | | | |
| In hay | 48.000 | 41.904 | 38.703 | 0.878 | 0.884 | 14.884 | 17.449 |
| In barley | 36.000 | 30.427 | 29.566 | 0.697 | 0.615 | 1.926 | 22.960 |
| Total | 84.000 | 72.331 | 68.269 | 1.575 | 1.499 | 16.810 | 40.409 |
| In faeces | 165.546 | 26.402 | 23.635 | 0.629 | 0.660 | 9 697 | 9.616 |
| Digested | | 45.929 | 44.634 | 0.946 | 0.839 | 7.113 | 30.793 |
| Coefficient | | 63.5 | 65.4 | 60.1 | 56.0 | 42.3 | 76.2 |
| Dig. from hay | | 22.293 | 21.171 | 0.490 | 0.416 | 6.534 | 11.098 |
| Dig. from barley | | 23.636 | 23.463 | 0.456 | 0.423 | 0.579 | 19.695 |
| Coff. of barley | | 77.7 | 79.4 | 65.4 | 68.8 | 30.1 | 85.8 |
| *Animal F* | | | | | | | |
| In hay | 78.000 | 68.094 | 62.892 | 1.427 | 1.437 | 24.187 | 28.354 |
| In faeces | 183.475 | 32.040 | 28.423 | 0.607 | 0.862 | 13.284 | 10.522 |
| Digested | | 36.054 | 34.469 | 0.820 | 0.575 | 10.903 | 17.832 |
| Coefficient | | 52.9 | 54.8 | 57.5 | 40.0 | 45.1 | 62.9 |

*†Collection period of 10 days.

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Cont nued*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| PERIOD 11—*Concluded* | | | | | | | |
| *Animal G* | | | | | | | |
| In oats | 36.000 | 30.798 | 29.668 | 0.632 | 1.127 | 3.859 | 20.998 |
| In faeces | 35.501 | 9.680 | 8.883 | 0.162 | 0.188 | 2.938 | 4.734 |
| Digested | | 21.118 | 20.785 | 0.470 | 0.939 | 0.921 | 16.264 |
| Coefficient | | 68.6 | 70.1 | 74.4 | 83.3 | 23.9 | 77.5 |
| PERIOD 12 | | | | | | | |
| *Animal B* | | | | | | | |
| In barley | 36.000 | 30.272 | 29.406 | 0.708 | 0.275 | 1.798 | 23.210 |
| In faeces | 28.816 | 6.546 | 5.995 | 0.166 | 0.166 | 2.363 | 2.546 |
| Digested | | 23.726 | 23.411 | 0.542 | 0.109 | − 0.565 | 20.664 |
| Coefficient | | 78.4 | 79.6 | 76.6 | 39.6 | − 31.4 | 89.0 |
| *Animal H* | | | | | | | |
| In hay | 60.000 | 52.992 | 48.943 | 1.103 | 1.245 | 18.812 | 21.992 |
| In oats | 36.000 | 30.974 | 29.878 | 0.694 | 1.233 | 3.866 | 20.737 |
| Total | 96.000 | 83.966 | 78.821 | 1.797 | 2.478 | 22.678 | 42.729 |
| In faeces | 208.991 | 37.273 | 33.754 | 0.710 | 0.783 | 15.096 | 13.634 |
| Digested | | 46.693 | 45.067 | 1.087 | 1.695 | 7.582 | 29.095 |
| Coefficient | | 55.6 | 57.2 | 60.5 | 68.4 | 33.4 | 68.1 |
| Dig. from hay | | 28.192 | 26.772 | 0.615 | 0.586 | 8.258 | 13.987 |
| Dig. from oats | | 18.501 | 18.295 | 0.472 | 1.109 | − 0.676 | 15.108 |
| Coeff. of oats | | 59.7 | 61.2 | 68.0 | 89.9 | − 17.5 | 72.9 |
| *Animal F* | | | | | | | |
| In hay | 60.000 | 52.992 | 48.943 | 1.103 | 1.245 | 18.812 | 21.992 |
| In barley | 36.000 | 30.272 | 29.406 | 0.708 | 0.275 | 1.798 | 23.210 |
| Total | 96.000 | 83.264 | 78.349 | 1.811 | 1.520 | 20.610 | 45.202 |
| In faeces | 167.382 | 29.674 | 26.704 | 0.636 | 0.694 | 11.858 | 10.481 |
| Digested | | 53.590 | 51.645 | 1.175 | 0.826 | 8.752 | 34.721 |
| Coefficient | | 64.4 | 65.9 | 64.9 | 54.3 | 42.5 | 76.8 |
| Dig. from hay | | 28.192 | 26.772 | 0.615 | 0.586 | 8.258 | 13.987 |
| Dig. from barley | | 25.398 | 24.873 | 0.560 | 0.240 | 0.494 | 20.734 |
| Coeff. of barley | | 83.9 | 84.6 | 79.1 | 87.3 | 27.5 | 89.3 |
| *Animal G* | | | | | | | |
| In hay | 84.000 | 74.189 | 68.521 | 1.544 | 1.743 | 26.337 | 30.788 |
| In faeces | 173.718 | 35.069 | 31.450 | 0.666 | 0.828 | 14.978 | 11.738 |
| Digested | | 39.120 | 37.071 | 0.878 | 0.915 | 11.359 | 19.050 |
| Coefficient | | 52.7 | 54.1 | 56.9 | 52.5 | 43.1 | 61.9 |
| PERIOD 13 | | | | | | | |
| *Animal B* | | | | | | | |
| In oats | 36.000 | 31.226 | 30.074 | 0.616 | 1.299 | 4.147 | 21.037 |
| In faeces | 38.116 | 10.303 | 9.534 | 0.162 | 0.191 | 3.657 | 4.776 |
| Digested | | 20.923 | 20.540 | 0.454 | 1.108 | 0.490 | 16.261 |
| Coefficient | | 67.0 | 68.3 | 73.7 | 85.3 | 11.8 | 77.3 |
| *Animal H* | | | | | | | |
| In barley | 36.000 | 30.733 | 29.891 | 0.640 | 0.621 | 1.853 | 23.689 |
| In faeces | 26.902 | 5.665 | 5.088 | 0.144 | 0.151 | 1.876 | 2.281 |
| Digested | | 25.068 | 24.803 | 0.496 | 0.470 | − 0.023 | 21.408 |
| Coefficient | | 81.6 | 83.0 | 77.5 | 75.7 | − 1.2 | 90.4 |

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Concluded*

| — | Original weight | Dry matter | Organic matter | Nitrogen | Ether extract | Crude fibre | N-free extract |
|---|---|---|---|---|---|---|---|
| | | | PERIOD 13—*Concluded* | | | | |
| *Animal F* | | | | | | | |
| In hay | 60.000 | 53.706 | 49.447 | 1.133 | 1.053 | 18.942 | 22.369 |
| In oats | 36.000 | 31.226 | 30.094 | 0.616 | 1.299 | 4.147 | 21.037 |
| Total | 96.000 | 84.932 | 79.541 | 1.749 | 2.352 | 23.089 | 43.406 |
| In faeces | 204.413 | 36.539 | 32.973 | 0.711 | 0.808 | 14.371 | 14.064 |
| Digested | | 48.393 | 46.568 | 1.038 | 1.544 | 8.718 | 29.342 |
| Coefficient | | 57.0 | 58.5 | 59.3 | 65.6 | 37.8 | 67.6 |
| Dig. from hay | | 28.572 | 27.048 | 0.632 | 0.496 | 8.316 | 14.227 |
| Dig. from oats | | 19.821 | 19.520 | 0.406 | 1.048 | 0.402 | 15.115 |
| Coeff. of oats | | 63.5 | 64.9 | 65.9 | 80.7 | 9.7 | 71.8 |
| *Animal G* | | | | | | | |
| In hay | 60.000 | 53.706 | 49.447 | 1.133 | 1.053 | 18.942 | 22.369 |
| In barley | 36.000 | 30.733 | 29.891 | 0.640 | 0.621 | 1.853 | 23.689 |
| Total | 96.000 | 84.439 | 79.338 | 1.773 | 1.674 | 20.795 | 46.058 |
| In faeces | 179.578 | 32.483 | 29.163 | 0.734 | 0.754 | 12.711 | 11.746 |
| Digested | | 51.956 | 50.175 | 1.039 | 0.920 | 8.084 | 34.312 |
| Coefficient | | 61.5 | 63.2 | 58.6 | 55.0 | 38.9 | 74.5 |
| Dig. from hay | | 28.572 | 27.048 | 0.632 | 0.496 | 8.316 | 14.227 |
| Dig. from barley | | 23.384 | 23.127 | 0.407 | 0.424 | − 0.232 | 20.085 |
| Coeff. of barley | | 76.1 | 77.4 | 63.6 | 68.3 | − 12.5 | 84.8 |
| | | | PERIOD 14 | | | | |
| *Animal H* | | | | | | | |
| In oats | 36.000 | 31.392 | 30.441 | 0.732 | 1.381 | 3.550 | 21.243 |
| In faeces | 41.376 | 8.914 | 8.213 | 0.193 | 0.199 | 3.181 | 3.800 |
| Digested | | 22.478 | 22.228 | 0.539 | 1.182 | 0.369 | 17.443 |
| Coefficient | | 71.6 | 73.0 | 73.6 | 85.6 | 10.4 | 82.1 |

TABLE 8.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF HAY AND MIXED RATIONS

(Coefficients in per cent; Animal numbers in brackets)

| Nutrient | 1938–1939 | | | | | 1939–40 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Period | Coefficients of digestibility | | | | Period | Coefficients of digestibility | | |
| | | Hay | Hay and barley | Hay and oats | Hay and oil cake | | Hay | Hay and barley | Hay and oats |
| Dry matter | 1 | 53.2(C) | 64.4(D) | 57.7(G) | 63.1(A) | 9 | 54.6(B) | – | 60.6(G) |
| | 2 | 55.3(A) | 66.6(E) | 58.3(B) | 61.8(F) | 10 | 52.4(H) | 63.5(B) | – |
| | 3 | 52.9(E) | 62.5(G) | 58.8(D) | 60.6(B) | 11 | 52.9(F) | 63.5(H) | 58.7(B) |
| | 4 | 52.6(G) | 63.0(F) | 56.1(C) | 63.4(E) | 12 | 52.7(G) | 64.4(F) | 55.6(H) |
| | 5 | 52.5(D) | 62.3(B) | 58.2(F) | 60.0(C) | 13 | – | 61.5(G) | 57.0(F) |
| | 6 | 52.5(F) | 63.9(A) | 61.2(E) | 61.7(D) | | | | |
| | 7 | 52.1(B) | 60.1(C) | 59.9(A) | 62.3(G) | | | | |
| Means | | 53.0 | 63.3 | 58.6 | 61.8 | | 53.2 | 63.2 | 58.0 |

TABLE 8.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF HAY AND MIXED RATIONS —*Concluded*

| Nutrient | 1938–1939 | | | | | 1939–40 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Per-iod | Coefficients of digestibility | | | | Per-iod | Coefficients of digestibility | | |
| | | Hay | Hay and barley | Hay and oats | Hay and oil cake | | Hay | Hay and barley | Hay and oats |
| Organic matter | 1 | 55.0 | 65.9 | 59.4 | 64.7 | 9 | 56.1 | – | 61.9 |
| | 2 | 57.2 | 68.3 | 59.7 | 63.3 | 10 | 53.6 | 65.7 | – |
| | 3 | 54.3 | 64.3 | 60.2 | 62.1 | 11 | 54.8 | 65.4 | 60.4 |
| | 4 | 54.4 | 64.8 | 57.9 | 65.2 | 12 | 54.1 | 65.9 | 57.2 |
| | 5 | 54.5 | 64.3 | 59.9 | 61.8 | 13 | – | 63.2 | 58.5 |
| | 6 | 54.4 | 65.9 | 63.2 | 63.4 | | | | |
| | 7 | 53.8 | 61.5 | 61.3 | 63.9 | | | | |
| Means | | 54.8 | 65.0 | 60.2 | 63.5 | | 54.7 | 65.1 | 59.5 |
| Nitrogen | 1 | 59.6 | 64.3 | 67.0 | 78.0 | 9 | 55.3 | – | 65.4 |
| | 2 | 60.6 | 68.2 | 67.2 | 76.4 | 10 | 53.5 | 62.4 | – |
| | 3 | 60.8 | 62.2 | 64.5 | 77.1 | 11 | 57.5 | 60.1 | 61.8 |
| | 4 | 58.1 | 62.2 | 61.6 | 77.2 | 12 | 56.9 | 64.9 | 60.5 |
| | 5 | 56.2 | 60.1 | 63.6 | 75.3 | 13 | – | 58.6 | 59.3 |
| | 6 | 50.3 | 59.4 | 65.5 | 76.4 | | | | |
| | 7 | 51.6 | 54.7 | 64.1 | 76.8 | | | | |
| Means | | 56.7 | 61.6 | 64.8 | 76.7 | | 55.8 | 61.5 | 61.8 |
| Ether extract | 1 | 47.8 | 61.4 | 62.3 | 76.7 | 9 | 47.4 | – | 64.3 |
| | 2 | 49.6 | 61.8 | 67.4 | 75.7 | 10 | 48.4 | 52.9 | – |
| | 3 | 42.7 | 47.3 | 66.8 | 75.5 | 11 | 40.0 | 56.0 | 65.2 |
| | 4 | 29.7 | 46.0 | 59.5 | 72.5 | 12 | 52.5 | 54.3 | 68.4 |
| | 5 | 34.0 | 49.6 | 64.1 | 67.3 | 13 | – | 55.0 | 65.6 |
| | 6 | 33.8 | 52.7 | 59.4 | 75.0 | | | | |
| | 7 | 40.4 | 54.2 | 68.6 | 79.5 | | | | |
| Means | | 39.7 | 53.3 | 64.0 | 74.6 | | 47.1 | 54.6 | 65.9 |
| Crude fibre | 1 | 40.4 | 34.7 | 35.4 | 36.6 | 9 | 45.7 | – | 42.6 |
| | 2 | 42.0 | 40.7 | 34.0 | 35.4 | 10 | 41.5 | 50.3 | – |
| | 3 | 40.9 | 36.9 | 38.7 | 35.0 | 11 | 45.1 | 42.3 | 51.1 |
| | 4 | 42.4 | 41.3 | 33.4 | 43.3 | 12 | 43.1 | 42.5 | 33.4 |
| | 5 | 44.5 | 38.6 | 37.7 | 39.7 | 13 | – | 38.9 | 37.8 |
| | 6 | 46.8 | 43.6 | 48.7 | 44.1 | | | | |
| | 7 | 44.1 | 38.5 | 41.4 | 42.6 | | | | |
| Means | | 43.0 | 39.2 | 38.5 | 39.5 | | 43.9 | 43.5 | 41.2 |
| N-free extract | 1 | 64.8 | 78.6 | 69.0 | 72.5 | 9 | 65.6 | – | 71.5 |
| | 2 | 67.8 | 79.4 | 69.3 | 71.4 | 10 | 64.0 | 73.3 | – |
| | 3 | 63.8 | 76.9 | 69.8 | 68.8 | 11 | 62.9 | 76.2 | 70.1 |
| | 4 | 64.3 | 76.1 | 69.1 | 71.3 | 12 | 61.9 | 76.8 | 68.1 |
| | 5 | 62.9 | 76.5 | 69.1 | 67.5 | 13 | – | 74.5 | 67.6 |
| | 6 | 62.6 | 77.9 | 71.3 | 68.4 | | | | |
| | 7 | 63.4 | 74.2 | 70.7 | 70.1 | | | | |
| Means | | 64.2 | 77.1 | 69.8 | 70.0 | | 63.6 | 75.2 | 69.3 |

TABLE 9.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF GRAINS

(Coefficients in per cent. Animal numbers in brackets)

| Nutrient | Year | Period | Barley | | Oats | | Oil cake | |
|---|---|---|---|---|---|---|---|---|
| | | | Observed | Calculated | Observed | Calculated | Observed | Calculated |
| Dry matter | 1938–39 | 1 | 85.9(E) | 83.3 | – | 65.4 | 75.1(B) | 79.2 |
| | | 2 | 84.0(C) | 89.2 | 65.8(D) | 67.1 | 74.0(G) | 76.0 |
| | | 3 | – | 78.0 | – | 68.3 | 78.7(A) | 72.4 |
| | | 4 | 81.0(A) | 79.5 | – | 61.2 | 78.5(D) | 79.7 |
| | | 5 | – | 77.7 | 74.5(A) | 66.8 | 79.4(E) | 71.1 |
| | | 6 | 80.8(B) | 82.0 | – | 74.8 | 78.8(C) | 75.4 |
| | | 7 | 82.9(D) | 72.0 | 74.0(E) | 71.5 | 79.7(F) | 77.3 |
| | | 8 | 76.2(G) | | 79.1(A) | | | |
| | | | | | 75.8(B) | | | |
| | | | | | 70.1(C) | | | |
| | | | | | 72.8(D) | | | |
| | | | | | 73.2(E) | | | |
| | Means | | 81.8 | 80.2 | 73.2 | 67.9 | 77.7 | 75.9 |
| | 1939–40 | 1 | 84.3(F) | – | – | 73.2 | | |
| | | 3 | 81.9(G) | 81.1 | 72.2(F) | – | | |
| | | 5 | – | 77.7 | 68.6(G) | 68.1 | | |
| | | 7 | 78.4(B) | 83.9 | – | 59.7 | | |
| | | 8 | 81.6(H) | 76.1 | 67.0(B) | 63.5 | | |
| | | 9 | – | – | 71.6(H) | – | | |
| | Means | | 81.6 | 79.7 | 69.9 | 66.1 | | |
| | General means | | 81.7 | 80.0 | 72.1 | 67.2 | | |
| Organic matter | 1938–39 | 1 | 87.4 | 83.3 | – | 66.8 | 77.5 | 80.3 |
| | | 2 | 85.3 | 89.6 | 68.4 | 67.6 | 76.9 | 76.7 |
| | | 3 | – | 79.0 | – | 68.8 | 80.2 | 73.1 |
| | | 4 | 82.8 | 80.4 | – | 62.8 | 80.8 | 81.2 |
| | | 5 | – | 79.2 | 75.6 | 68.0 | 81.1 | 72.6 |
| | | 6 | 82.0 | 83.3 | – | 76.6 | 80.5 | 76.7 |
| | | 7 | 84.1 | 72.3 | 75.5 | 71.8 | 80.8 | 78.2 |
| | | 8 | 79.3 | – | 80.7 | – | | |
| | | | | | 77.6 | – | | |
| | | | | | 72.1 | – | | |
| | | | | | 74.6 | – | | |
| | | | | | 74.9 | – | | |
| | Means | | 83.5 | 81.0 | 74.9 | 68.9 | 79.7 | 77.0 |
| | 1939–40 | 1 | 86.0 | – | – | 73.9 | | |
| | | 3 | 84.0 | 83.7 | 73.9 | – | | |
| | | 5 | – | 79.4 | 70.1 | 69.6 | | |
| | | 7 | 79.6 | 84.6 | – | 61.2 | | |
| | | 8 | 83.0 | 77.4 | 68.3 | 64.9 | | |
| | | 9 | – | – | 73.0 | – | | |
| | Means | | 83.2 | 81.3 | 71.3 | 67.4 | | |
| | General means | | 83.4 | 81.1 | 73.7 | 68.4 | | |

TABLE 9.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF GRAINS—*Continued*

| Nutrient | Year | Period | Barley | | Oats | | Oil cake | |
|---|---|---|---|---|---|---|---|---|
| | | | Observed | Calculated | Observed | Calculated | Observed | Calculated |
| Nitrogen | 1938–39 | 1 | 77.7 | 76.7 | – | 81.5 | 86.5 | 89.5 |
| | | 2 | 80.7 | 87.0 | 77.8 | 81.7 | 84.6 | 87.1 |
| | | 3 | – | 70.9 | – | 77.1 | 88.2 | 87.4 |
| | | 4 | 77.1 | 71.0 | – | 69.3 | 88.5 | 87.4 |
| | | 5 | – | 66.0 | 79.4 | 74.4 | 88.7 | 85.1 |
| | | 6 | 73.4 | 63.4 | – | 78.7 | 88.5 | 85.3 |
| | | 7 | 69.1 | 51.9 | 76.0 | 74.2 | 89.1 | 85.3 |
| | | 8 | 62.1 | – | 74.4 | – | – | – |
| | | | – | – | 77.6 | – | – | – |
| | | | – | – | 73.2 | – | – | – |
| | | | – | – | 78.0 | – | – | – |
| | | | – | – | 75.0 | – | – | – |
| | Means | | 73.4 | 69.6 | 76.4 | 76.7 | 87.7 | 86.7 |
| | 1939–40 | 1 | 76.0 | – | – | 78.8 | | |
| | | 3 | 80.7 | 72.4 | 80.1 | – | | |
| | | 5 | – | 65.4 | 74.4 | 72.3 | | |
| | | 7 | 76.6 | 79.1 | – | 68.0 | | |
| | | 8 | 77.5 | 63.6 | 73.7 | 65.9 | | |
| | | 9 | – | – | 73.6 | – | | |
| | Means | | 77.7 | 70.1 | 75.5 | 71.3 | | |
| | General means | | 75.1 | 69.8 | 76.1 | 74.7 | | |
| Ether extract | 1938–39 | 1 | 70.2 | 106.2 | – | 87.0 | 85.4 | 96.3 |
| | | 2 | 68.3 | 107.7 | 67.4 | 97.7 | 81.6 | 94.8 |
| | | 3 | – | 62.0 | – | 91.8 | 88.8 | 93.7 |
| | | 4 | 68.8 | 56.3 | – | 75.4 | 89.8 | 87.3 |
| | | 5 | – | 69.3 | 85.5 | 84.5 | 92.0 | 82.7 |
| | | 6 | 55.5 | 75.2 | – | 79.6 | 92.3 | 91.2 |
| | | 7 | 50.0 | 77.3 | 86.4 | 90.9 | 92.6 | 97.8 |
| | | 8 | 56.2 | – | 81.7 | – | – | – |
| | | | – | – | 85.2 | – | – | – |
| | | | – | – | 75.5 | – | – | – |
| | | | – | – | 80.7 | – | – | – |
| | | | – | – | 82.0 | – | – | – |
| | Means | | 61.5 | 79.1 | 80.6 | 86.7 | 88.9 | 92.0 |
| | 1939–40 | 1 | 56.1 | – | – | 88.5 | | |
| | | 3 | 60.1 | 69.5 | 76.1 | – | | |
| | | 5 | – | 68.8 | 83.3 | 83.1 | | |
| | | 7 | 39.6 | 87.3 | – | 89.9 | | |
| | | 8 | 75.7 | 68.3 | 85.3 | 80.7 | | |
| | | 9 | – | – | 85.6 | | | |
| | Means | | 57.9 | 73.5 | 82.6 | 85.6 | | |
| | General means | | 60.0 | 77.1 | 81.2 | 86.3 | | |

TABLE 9.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF GRAINS—*Concluded*

| Nutrient | Year | Period | Barley | | Oats | | Oil cake | |
|---|---|---|---|---|---|---|---|---|
| | | | Observed | Calculated | Observed | Calculated | Observed | Calculated |
| Total carbohydrates | 1938–39 | 1 | 89.3 | 82.9 | – | 62.8 | 71.6 | 71.6 |
| | | 2 | 86.6 | 88.7 | 66.9 | 62.1 | 71.7 | 67.8 |
| | | 3 | – | 80.7 | – | 66.4 | 74.7 | 61.4 |
| | | 4 | 84.0 | 82.5 | – | 61.7 | 75.3 | 76.6 |
| | | 5 | – | 81.3 | 73.9 | 65.4 | 75.4 | 64.1 |
| | | 6 | 84.1 | 87.3 | – | 77.6 | 73.9 | 71.6 |
| | | 7 | 87.4 | 76.5 | 74.7 | 70.8 | 74.6 | 73.3 |
| | | 8 | 82.3 | – | 81.4 | – | – | – |
| | | | – | – | 76.8 | – | – | – |
| | | | – | – | 70.9 | – | – | – |
| | | | – | – | 73.6 | – | – | – |
| | | | – | – | 74.1 | – | – | – |
| | Means | | 85.6 | 82.8 | 74.0 | 66.7 | 73.9 | 69.5 |
| | 1939–40 | 1 | 87.3 | – | – | 73.2 | | |
| | | 3 | 84.7 | 84.7 | 72.4 | – | | |
| | | 5 | – | 81.5 | 69.1 | 69.1 | | |
| | | 7 | 80.4 | 84.9 | – | 58.7 | | |
| | | 8 | 83.7 | 77.7 | 66.5 | 61.6 | | |
| | | 9 | – | – | 71.8 | – | | |
| | Means | | 84.0 | 82.2 | 70.0 | 65.7 | | |
| | General means | | 85.0 | 82.6 | 72.7 | 66.3 | | |
| T.D.N. in dry matter | 1938–39 | 1 | 85.85 | 80.89 | – | 68.12 | 81.41 | 84.24 |
| | | 2 | 83.39 | 87.85 | 69.13 | 68.53 | 80.15 | 81.28 |
| | | 3 | – | 77.44 | – | 71.20 | 83.85 | 77.44 |
| | | 4 | 81.65 | 79.27 | – | 62.97 | 84.50 | 84.41 |
| | | 5 | – | 77.95 | 75.56 | 68.06 | 85.13 | 76.56 |
| | | 6 | 80.76 | 83.11 | – | 78.88 | 84.09 | 81.67 |
| | | 7 | 83.06 | 72.93 | 76.48 | 73.53 | 84.79 | 83.57 |
| | | 8 | 78.78 | – | 81.46 | – | – | – |
| | | | – | – | 78.58 | | | |
| | | | – | – | 72.45 | | | |
| | | | – | – | 75.67 | | | |
| | | | – | – | 75.75 | | | |
| | Means | | 82.25 | 79.92 | 75.64 | 70.18 | 83.42 | 81.31 |
| | 1939–40 | 1 | 84.17 | – | – | 75.85 | | |
| | | 3 | 83.10 | 81.83 | 73.57 | – | | |
| | | 5 | – | 78.72 | 71.94 | 71.60 | | |
| | | 7 | 77.90 | 83.74 | – | 63.60 | | |
| | | 8 | 82.26 | 75.22 | 70.43 | 65.06 | | |
| | | 9 | – | – | 73.49 | – | | |
| | Means | | 81.86 | 79.88 | 72.36 | 69.03 | | |
| | General means | | 82.09 | 79.90 | 74.54 | 69.76 | | |

# BORON DEFICIENCY IN APRICOTS[1]

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[Received for publication January 16, 1941]

The work reported herein forms part of a program of investigation into the physiological disorders of the fruit trees of southern British Columbia. The demonstration by McLarty (2) that certain of these disorders are due to boron deficiency has made necessary a definition of symptoms of boron deficiency on all the orchard crops grown in this region. This paper describes the symptoms on the apricot on experimental plants grown in sand culture and on trees growing under field conditions.

## EXPERIMENTAL

### Materials and method

Apricot trees were grown in asphaltum coated galvanized iron tubs filled with sand which was taken from the shore of Lake Okanagan at Summerland, B.C. Each tub was 5 feet in diameter and 14 inches deep. A drain hole of $\frac{3}{4}$-inch diameter was provided in the bottom about 6 inches from the periphery and the tubs placed so that there was a slope of about 1 inch towards the hole.

In the spring of 1935 a 1-year old apricot tree was planted in each tub. Throughout 1935 and 1936 the sand was watered with a nutrient solution made mainly from commercial fertilizer materials. No boron was added, but neither was any precaution taken to exclude the possibility of boron contamination. All the trees received the same treatment and, with the exception of some which were winter killed in 1936 and had to be replaced, all appeared to grow normally. There were 13 trees in the experiment.

In the spring of 1937 these trees were divided into 2 groups consisting of 6 and 7 respectively and differential treatment was begun. Those in the first group, 6 trees, were given a complete nutrient ration made from "C.P." salts and supplemented with boric acid; those of the other group, 7 trees, were given the same ration, but with the boron omitted.

## RESULTS

The trees in both groups continued to thrive throughout the years 1937, 1938, and 1939. There was no detectable difference in their growth nor any abnormality in their foliage or fruit. Analyses of leaf and fruit samples showed no significant difference in boron content until 1939 when there was a decided drop in the boron content of the fruit from the trees that were not receiving boron (Table 1). The following spring, 1940, deficiency symptoms were manifested in all of these trees.

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Table 1.—The boron content* of apricot leaves† and fruit from plants grown in sand culture with and without boron added

| Tree No. | Boron, p.p.m., dry weight | | | | |
|---|---|---|---|---|---|
| | 1937 Leaves | 1938 Leaves | 1940 Leaves | 1938 Fruit | 1939 Fruit |
| Receiving boron | | | | | |
| A3 | 29.8 | 27.1 | 29.1 | 60.0 | 42.8 |
| A5 | 32.8 | 32.8 | 29.5 | 50.5 | 62.6 |
| A7 | 26.5 | 34.1 | 26.7 | 40.4 | 57.0 |
| A11 | — | 37.4 | 22.7 | — | 17.3 |
| A19 | — | 38.9 | 21.6 | — | 20.1 |
| B1 | 32.8 | 33.8 | 25.8 | 38.5 | 32.0 |
| Receiving boron | | | | | |
| A2 | 28.7 | 34.4 | 5.8 | 29.6 | 6.8 |
| A6 | 25.0 | 25.9 | — | 12.3 | 7.1 |
| A8 | 26.1 | 31.1 | — | 32.1 | 6.9 |
| A10 | — | 37.8 | 2.5 | — | 6.0 |
| A12 | 25.6 | 28.5 | 6.8 | — | 9.7 |
| A17 | 24.6 | 31.3 | 5.7 | — | — |
| B3 | 25.2 | 31.3 | — | 13.7 | 7.9 |

* Determined by the method described by Woodbridge (3).
† Collected in the autumn in 1937 and 1938 but in June in 1940.

In the most severe cases, there was a dying back of the terminal twigs. Where this occurred, the twigs appeared healthy in the early spring; the cambium was alive and there was no shrivelling of the bark. But the buds instead of breaking their dormancy normally, either did not develop at all, or, if they did, only reached the "green tip" stage at which they turned black, shrivelled and died (Plate I, 1). The cambium and bark died soon after and the twigs began to shrivel progressively from their tips back.

Two of the 7 trees succumbed in this fashion without developing any foliage, 2, although severely affected with die-back, did develop some, while the remaining 3 showed symptoms only in the first leaves that developed, the later leaves being apparently normal. Some leaves were from buds that had only sufficient vitality to develop past the "green tip" stage. They were extremely dwarfed, more or less spatulate in form and curled up at the margins. Most of them began to blacken at the tip soon after they unfolded (Plate I, 2 and 3). Eventually they shrivelled and fell off. From this extreme on the one hand to what appeared to be perfectly normal leaves on the other, there was a variety of intergrades (Plate I, 4 and 5). In general the leaves on the deficient trees were brittle, narrower, and paler between the veins. In some cases the mid-rib and main lateral veins were thickened (Plate I, 6) and often the leaves assumed a characteristic boat-like form (Plate I, 7). None of the deficient trees bore fruit.

## FIELD OBSERVATION

Die-back and foliage symptoms similar to those described from the plants grown in sand were found in several apricot orchards in the Okanagan valley in the spring of 1940. Chemical analysis of twigs from one severely affected tree showed that the boron content was 4.5 p.p.m., whereas that of


PLATE I. Boron deficiency symptoms in apricot—Fitzpatrick and Woodbridge. 1. Twig showing buds which appeared normal but which failed to develop. 2 and 3. Twigs showing leaves which were blackened at the tips and were extremely dwarfed. 4. Branch showing foliage symptoms. 5. Twig showing foliage symptoms. 6. Leaves showing thickened midribs and laminal distortion. 7. Leaf showing characteristic boat-like form.

2 healthy trees was 20.8 and 20.0 p.p.m., respectively. For the most part the trees which were affected were in young apricot plantings on land which had not yet been treated with boric acid. In one block of 44 trees of a 1937 planting no less than 27 trees were affected in 1940; of these, 14 were so severely affected that none of their buds had developed leaves up to May 9, while the remaining 13 at that time showed die-back and more or less severe leaf symptoms. In order to save the planting, boric acid solution, 4 lb. in 100 gal. of water, was sprayed on these trees in May and they subsequently recovered.

Fruit symptoms of boron deficiency such as have been described by Askew and Williams (1) have been reported from a few orchards but this manifestation of the deficiency has never been common in the Okanagan.

## SUMMARY

The effects of boron deficiency on apricot range from complete inhibition of growth in the spring, with subsequent death of the tree, to comparatively mild leaf symptoms, apparent only on the first leaves to develop. Characteristically, these effects occur together in the same tree so that certain branches die back completely while others grow more or less normally.

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2. McLarty, H. R. Tree injections with boron and other materials as a control for drought spot and corky core of apple. Sci. Agric. 16 : 625-633. 1936.

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## BOOK REVIEW

"Commercial Fertilizers" Their Source and Use. Third Edition. Gilbeart H. Collins. Publishers: The Blakiston Company, Philadelphia. $4.50.

The latest edition of this book will doubtless prove very satisfactory to the agricultural students for whom it was primarily written as well as to many who are interested in various ways in the subject of fertilizers.

It commences with an outline of the origin and development of the use of fertilizers, following this with chapters on the production and use of the various materials employed for their content of nitrogen, phosphoric acid and potash. Brief outlines of the chemistry of the different manufacturing processes are given, sufficient to enable a student to obtain a grasp of the principle reactions.

Chapters are devoted to the secondary and rarer essential elements of plant growth and to the elements in some fertilizers which are not considered essential, such as chlorine, sodium and silicon.

One chapter deals with the very important question of soil reaction and its adjustment. The principles underlying the purchase of fertilizers and of their use are considered in considerable detail.

In the final chapter the placement of fertilizers and their effect upon germination is well described and brought up to date.

Throughout the book the author has used data from various experiments to emphasize his points. Specific fertilizer recommendations for various crops are, very wisely, not given.

A fairly comprehensive bibliography is added, followed by author and subject indexes.

—H. S. Hammond.

"Modern Fruit Production" by Joseph Harvey Gourley and Freeman Smith Howlett. The Macmillan Company, New York. ($4.50).

This book represents a complete re-writing and expansion of the "Text Book of Pomology". While a few chapters of the book remain much the same as they were in the original text the bulk of the material is entirely new.

The aim of the authors is to present the most acceptable practices of modern fruit growing in America to-day and at the same time to set forth the fundamentals on which all successful fruit culture must ultimately rest. This has been accomplished in such a way that the book is of use not only to the practical grower but also the student of Pomology.

The opening chapter surveys the fruit industry as a whole and dwells briefly on its importance in United States Agriculture. Since little biological knowledge on the part of the reader is assumed, two chapters are

devoted to the morphology and physiology of fruit plants. Under the heading of site and soil for fruit plantations more space is usefully devoted to a discussion of orchard soils and the intelligent use of soil surveys in selecting suitable orchard sites. The chapters on soil management will be found particularly instructive and much data is presented from long time experiments on performance of tree fruits under clean cultivation and grass sod culture. Chapters on pruning, thinning and storage embody all the latest information available and limited space is devoted to the storage of fruit under refrigerated gas storage. The section dealing with winter injury has been extended to cover the vast amount of information accumulated following recent test winters. A very valuable addition to this book is the chapter dealing with physiological disorders which are becoming so prevalent in fruit plantations. In chapter 15 on propagation and stock, the processes of raising rootstocks and of budding and grafting are clearly described, also considerable attention is given to stocks in relation to specific fruits, including hardy seedling rootstocks, the East Malling vegetative stocks and double-working employing hardy intermediates.

This book is well printed and the illustrations well chosen and clearly reproduced. The aim of the authors has been fully realized and the result is a valuable textbook for the student and a fund of reliable information for the grower. It will make a very welcome addition to the library of the Pomologist and the commercial grower alike.

—D. S. Blair.

Imperial Bureau of Horticulture and Plantation Crops. Index to Horticultural Abstracts Volumes I – X, 1931–1940. I.B.H.P.C., East Malling, Kent, England, 1941, pp. 160. Price, 25/–.

At the first Imperial Horticultural Conference held in London in August, 1930, the following resolution was adopted: "That a commentary on current horticultural literature is desirable and should take the form of summaries of sufficient length to indicate the contents and scope of the papers concerned."

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## ERRATA

In *Scientific Agriculture* 21: 10, June, 1941, in the article entitled "The Effect of Having Rows Different Distances Apart in Rod Row Plot Tests of Wheat, Oats and Barley", by J. B. Harrington, the column headed "Height of plant in inches" should be "Height of plant in centimetres" in Tables 5, 6 and 7.

In *Scientific Agriculture* 22: 3, November, 1941, in the article entitled "Removal of Moisture from Honey", by W. A. Stephens, the obelisk on pp. 163, 164, and 165 refers to "Relative humidity of the air" p. 165 instead of p. 160.

In *Scientific Agriculture* 22: 3, November, 1941, in the article entitled "Vacuum Fumigation for Insect Control," by H. A. U. Monro, p. 173, 1st para. "Effect on Insects", line 13, "sub-stratosphere" should read "stratosphere."